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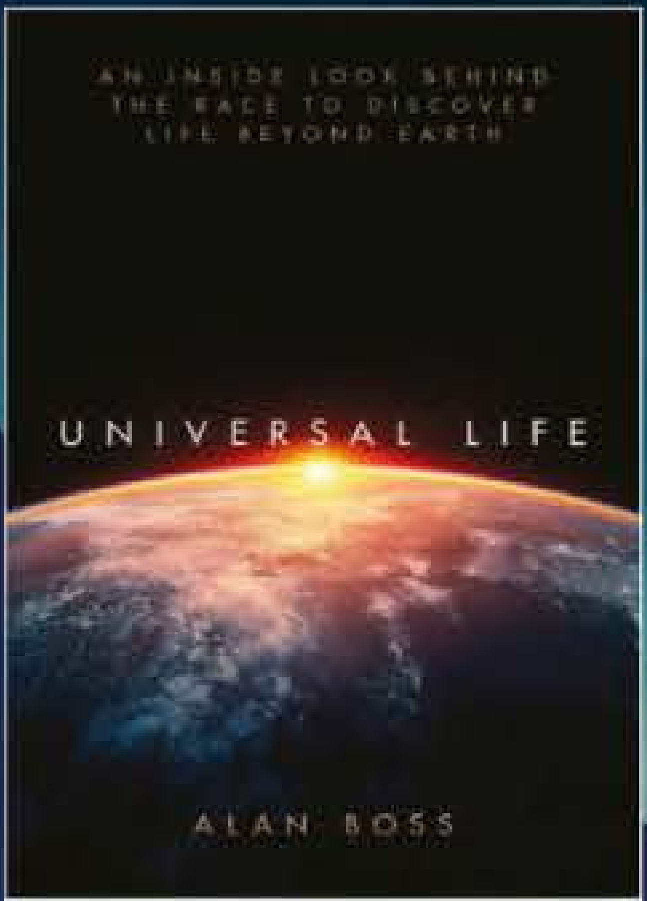

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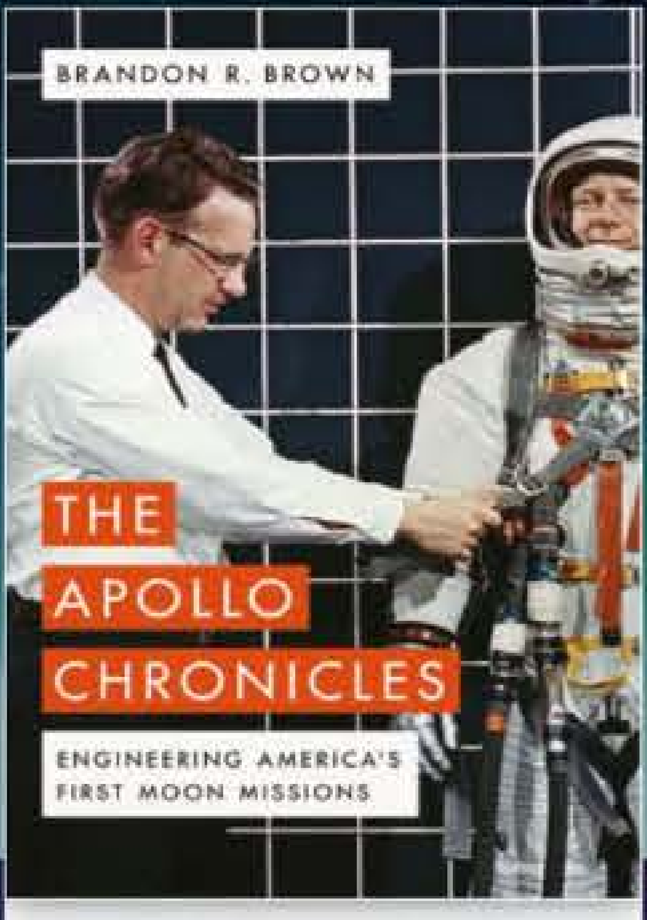

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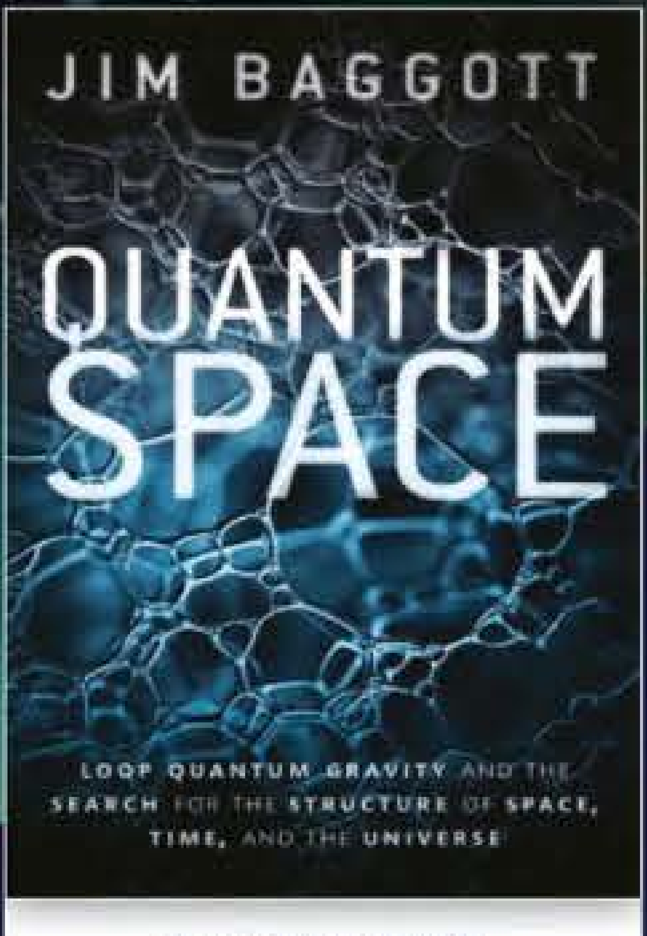

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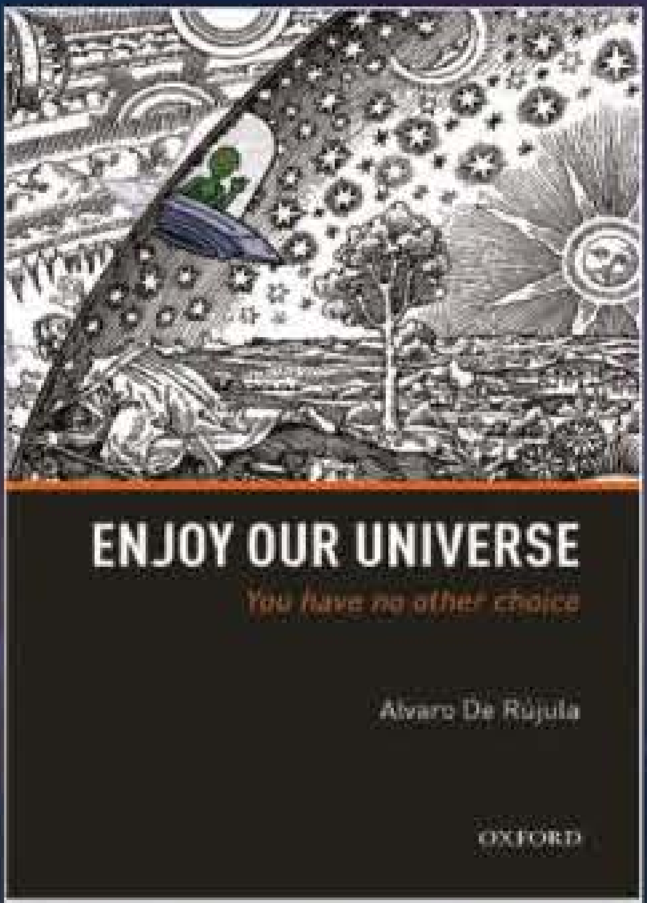

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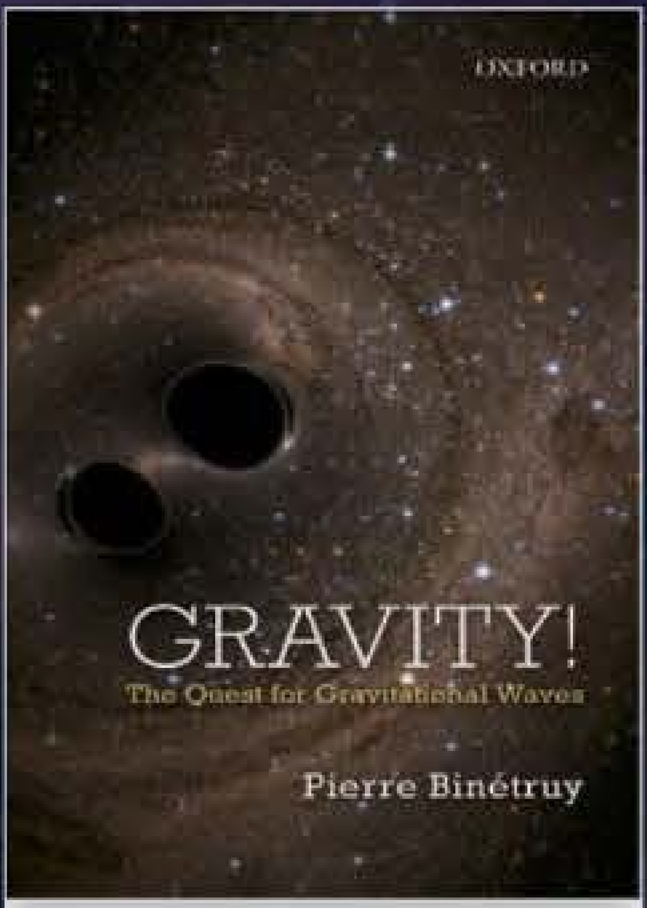

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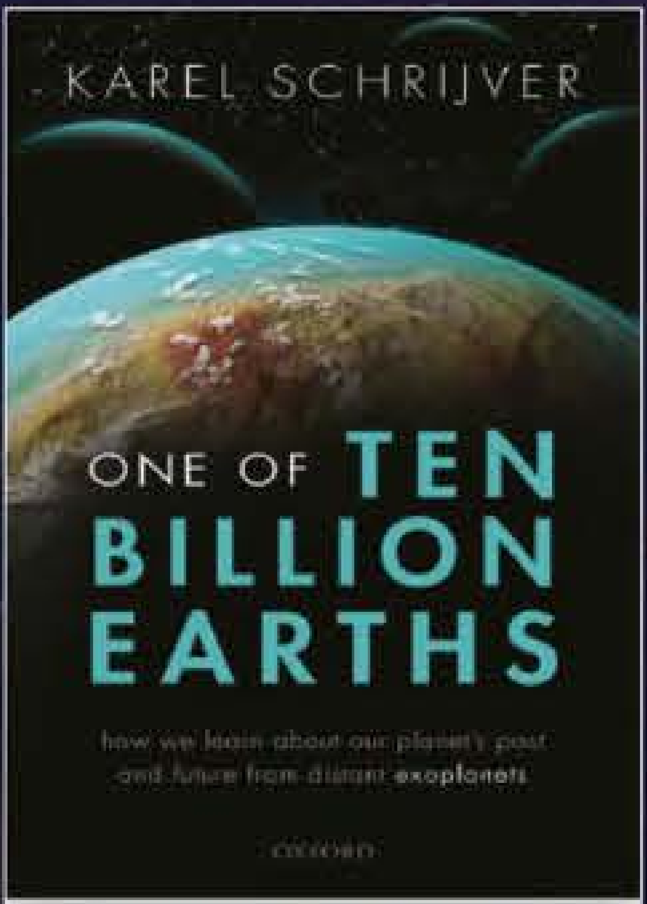

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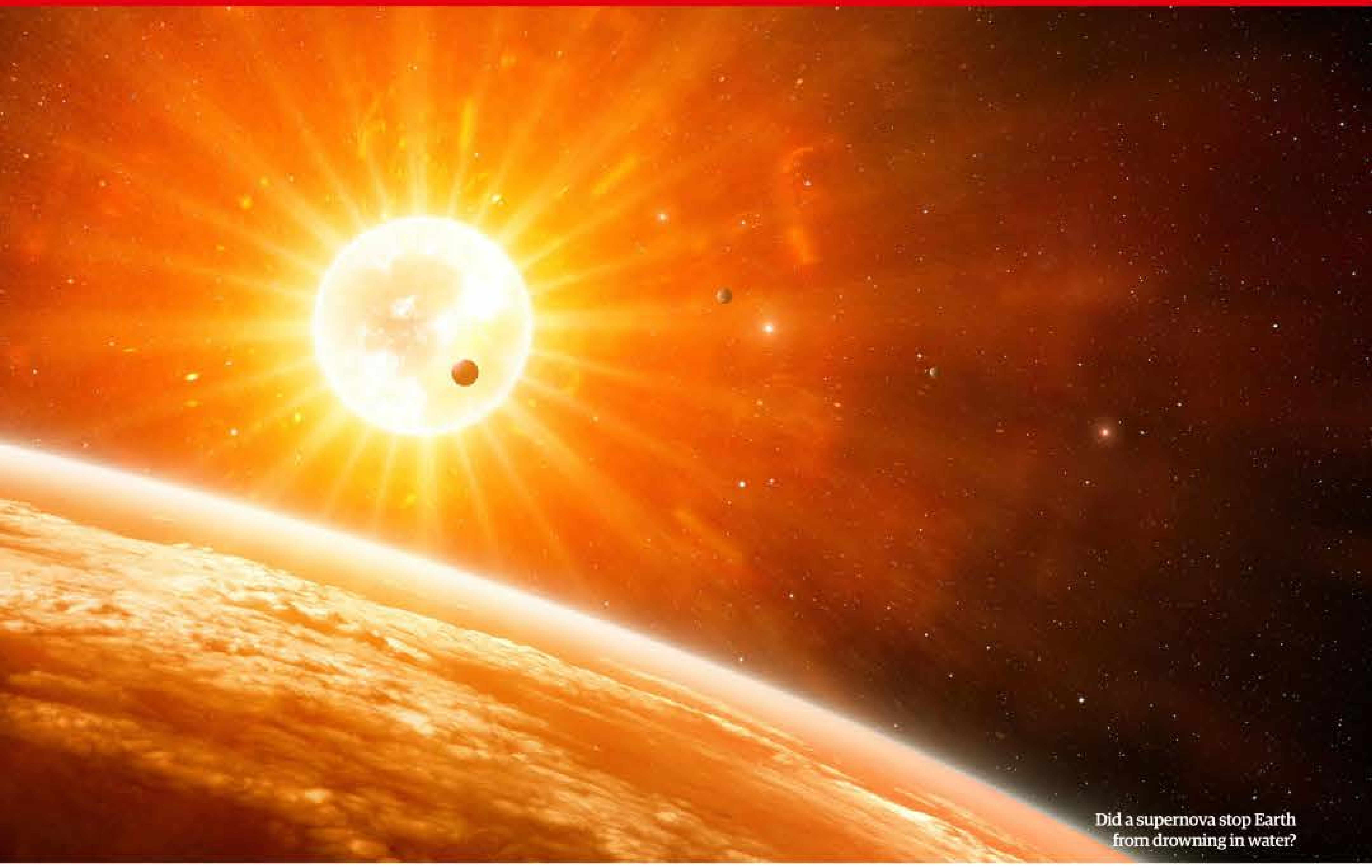
Did a supernova stop Earth from drowning in water?

© Tobias Roetsch

Welcome

The Black Knight satellite has been at the centre of conspiracy theories for decades, passed down through generations ever since engineer and inventor Nikola Tesla suspected that he heard 'natural extraterrestrial sources' during a radio experiment back in 1899. In essence, the theory claims that an extraterrestrial spacecraft loops around the Earth in an almost-polar orbit, with conspiracy theorists claiming that NASA is covering up its existence and origin.

As you'll discover in this issue of **All About Space**, we've started our series of myth-busting features that reveal the scientific explanations behind the universe's greatest conspiracy theories. And, this month, we kick off with unravelling the mystery of the Black Knight. Was it an alien spacecraft being covered up by the US government or is there a much more logical reason for it? We have the photos, experts and evidence that close the case on one of the greatest puzzles in the history of space exploration.

We've got plenty lined up for you – from the hunt for another universe before the Big Bang, an anti-universe where everything is the exact opposite to what we perceive to be our observable cosmos, to the strangest things launched into space, which includes the pizza and Lego figurines that have accompanied astronauts on their voyages beyond the Kármán line. Enjoy the issue!

Gemma Lavender
Editor-in-Chief

Our contributors include...

Giles Sparrow
Space science writer
Could there be a universe before time? Giles gets the details of evidence discovered by cosmologists on the hunt. Head over to page 16 for his full report.

Lee Cavendish
Staff writer
Lee caught up with the biographer of Apollo 11 astronaut Neil Armstrong this issue, who revealed exclusive insight into the life of the first man on the Moon.

Ian Evenden
Space science writer
Did a supernova stop early Earth from drowning in water? That's what Ian has discovered – and without it, life as we know it might not have evolved.

David Crookes
Science journalist
With the Opportunity mission officially over, David fondly looks back at some of the rover's greatest achievements during almost 15 years on the surface of Mars.

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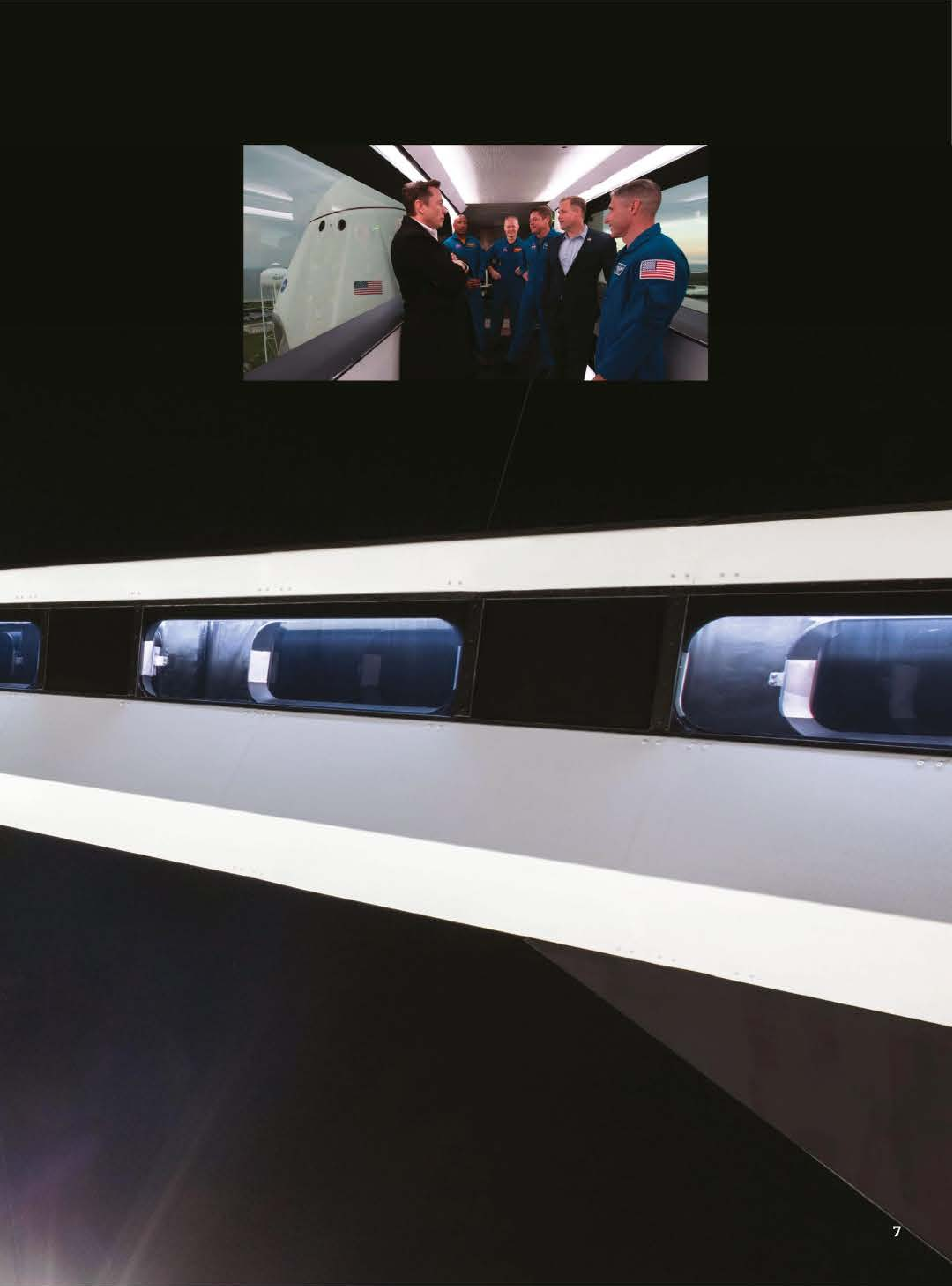
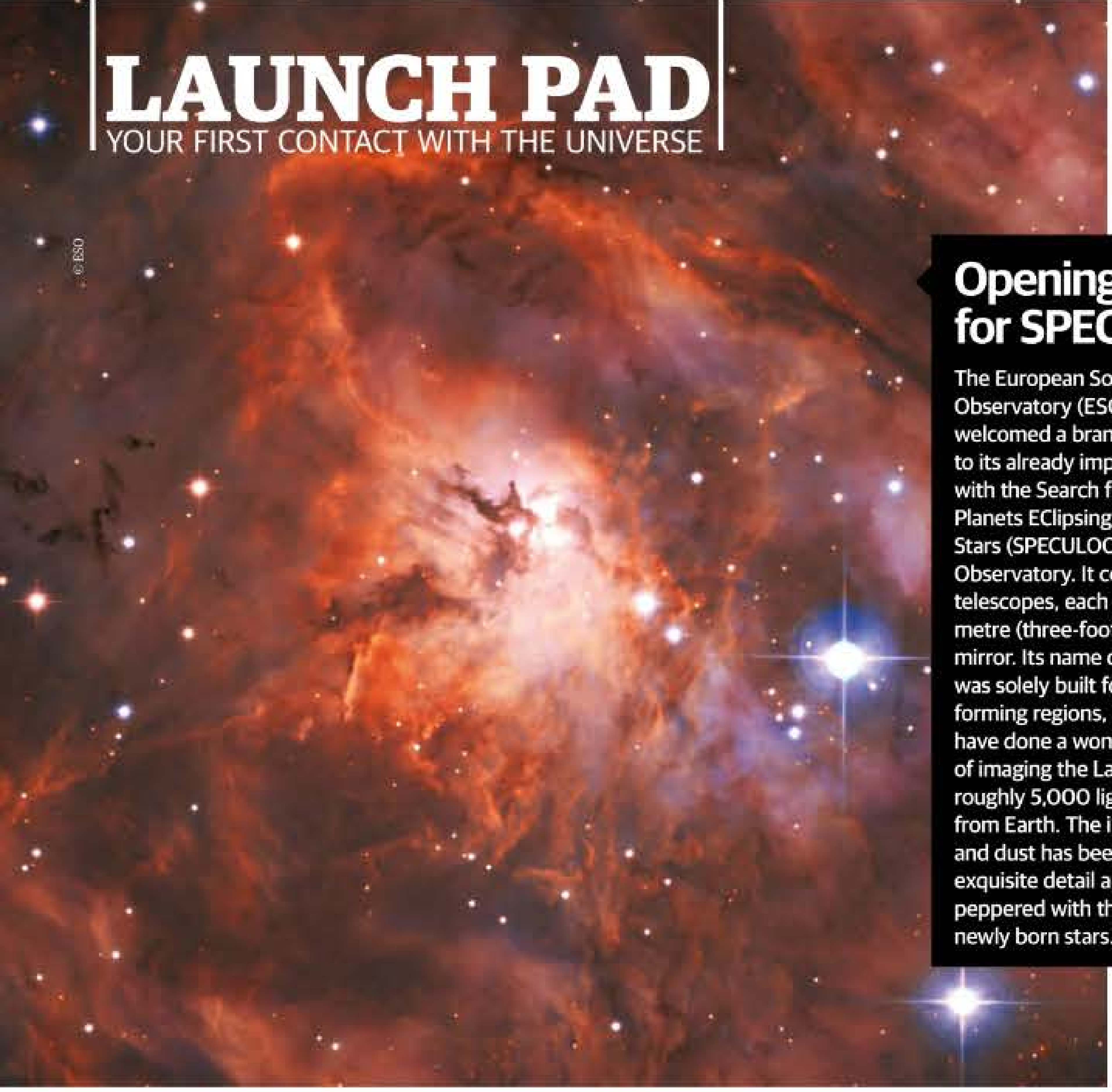
YOUR FIRST CONTACT WITH THE UNIVERSE

Ready for a historical launch

SpaceX and NASA completed an outstanding rendezvous with the International Space Station (ISS) in the early days of March 2019. In this incredible collaborative effort, SpaceX launched its Crew Dragon spacecraft from NASA's Kennedy Space Center in Florida, United States. After 18 orbits around Earth, the ISS successfully captured the spacecraft using a new international docking mechanism attached to the space station's Harmony module. Before launch the major players gathered in the access arm, including (from left to right of inset image) SpaceX CEO and chief designer Elon Musk, NASA astronauts Victor Glover, Doug Hurley and Bob Behnken, NASA administrator Jim Bridenstine and NASA astronaut Mike Hopkins.

© NASA; SpaceX





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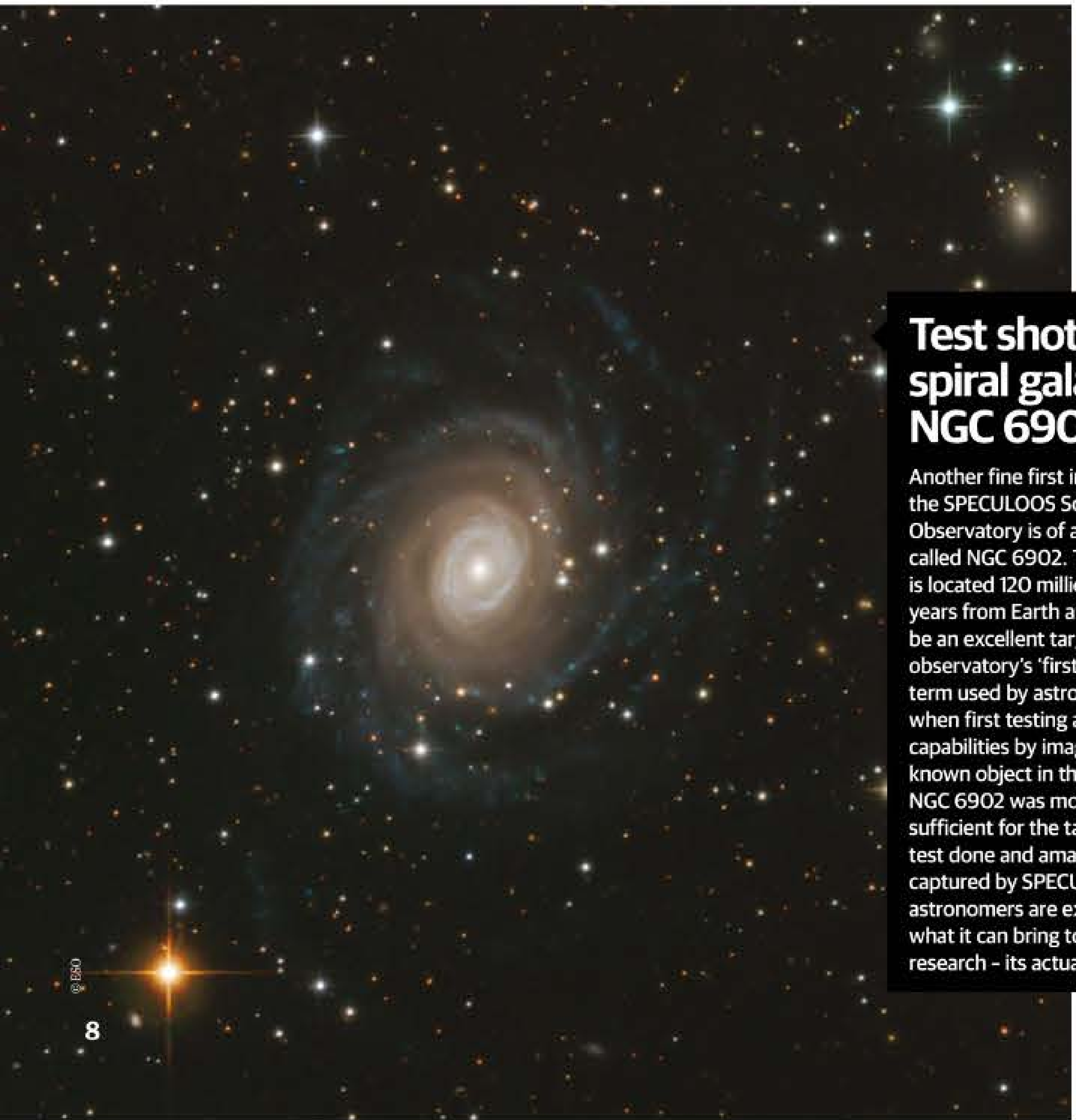
Opening shot for SPECULOOS

The European Southern Observatory (ESO) has recently welcomed a brand-new facility to its already impressive team with the Search for habitable Planets EClipsing ULtra-cOOl Stars (SPECULOOS) Southern Observatory. It consists of four telescopes, each with a one-metre (three-foot) primary mirror. Its name does not mean it was solely built for imaging star-forming regions, but astronomers have done a wonderful job here of imaging the Lagoon Nebula, roughly 5,000 light years away from Earth. The illuminated gas and dust has been pictured with exquisite detail and contrast, peppered with the twinkling of newly born stars.



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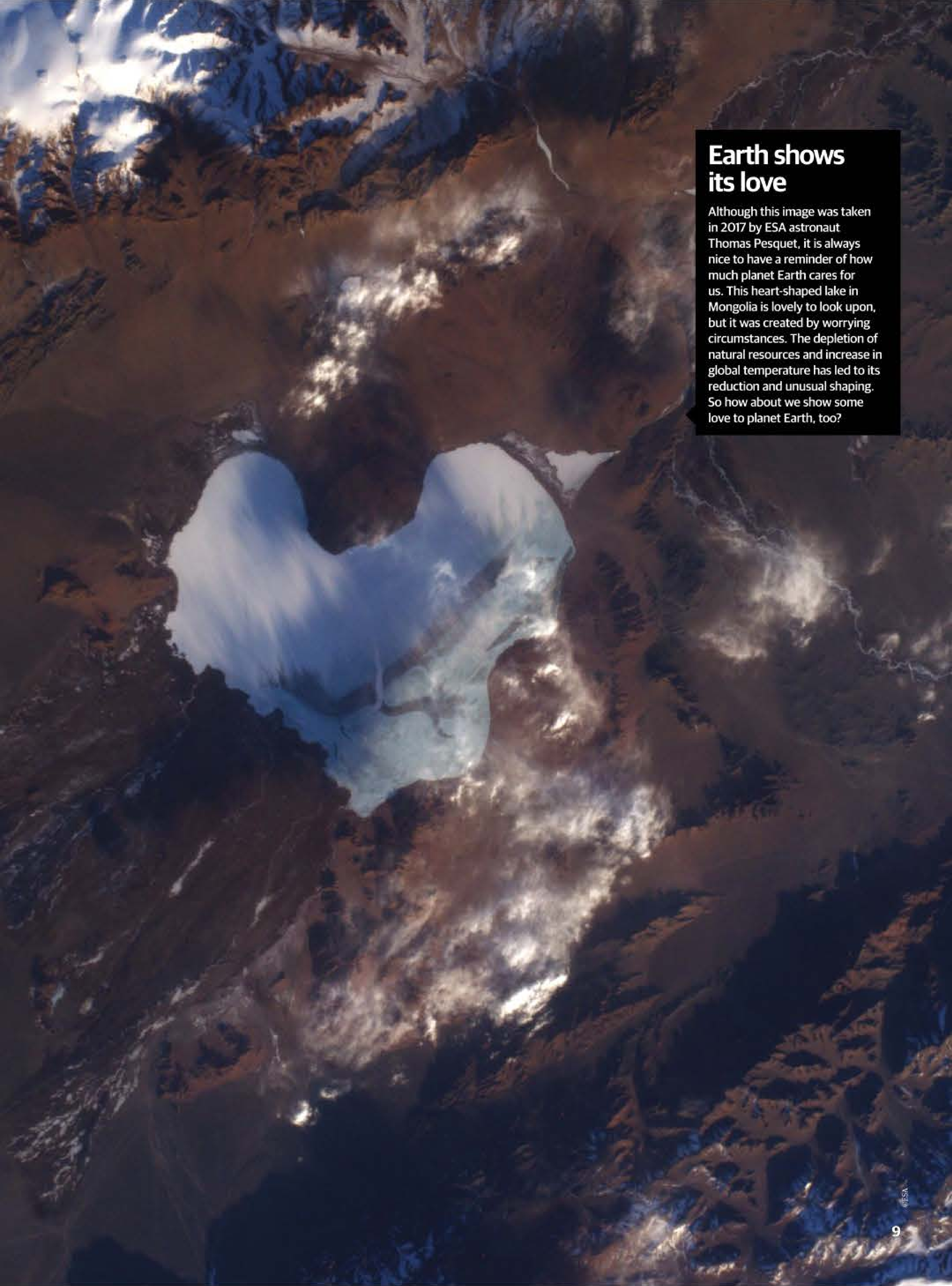
Test shot of spiral galaxy NGC 6902

Another fine first image for the SPECULOOS Southern Observatory is of a spiral galaxy called NGC 6902. This structure is located 120 million light years from Earth and proved to be an excellent target for the observatory's 'first light', a term used by astronomers when first testing a telescope's capabilities by imaging a well-known object in the night sky. NGC 6902 was more than sufficient for the task. With the test done and amazing images captured by SPECULOOS, astronomers are excited to see what it can bring to exoplanetary research – its actual purpose!



Earth shows its love

Although this image was taken in 2017 by ESA astronaut Thomas Pesquet, it is always nice to have a reminder of how much planet Earth cares for us. This heart-shaped lake in Mongolia is lovely to look upon, but it was created by worrying circumstances. The depletion of natural resources and increase in global temperature has led to its reduction and unusual shaping. So how about we show some love to planet Earth, too?

©ESA

SpaceShipTwo returns to space

Virgin Galactic has been flying to commercial-spaceflight prominence with its second successful launch in the space of ten weeks, carrying three people onboard. Virgin Galactic's SpaceShipTwo Unity reached space for the first time in December 2018, but this second flight on 22 February 2019 reached higher altitudes and faster speeds. SpaceShipTwo was carried into the sky on the 'mothership' of Virgin Galactic's quadjet cargo aircraft known as WhiteKnightTwo. The journey led Chief Pilot Dave Mackay, Pilot Mike Masucci and Chief Astronaut Beth Modes into space, becoming the 569th, 570th and 571st people to fly into space, respectively.

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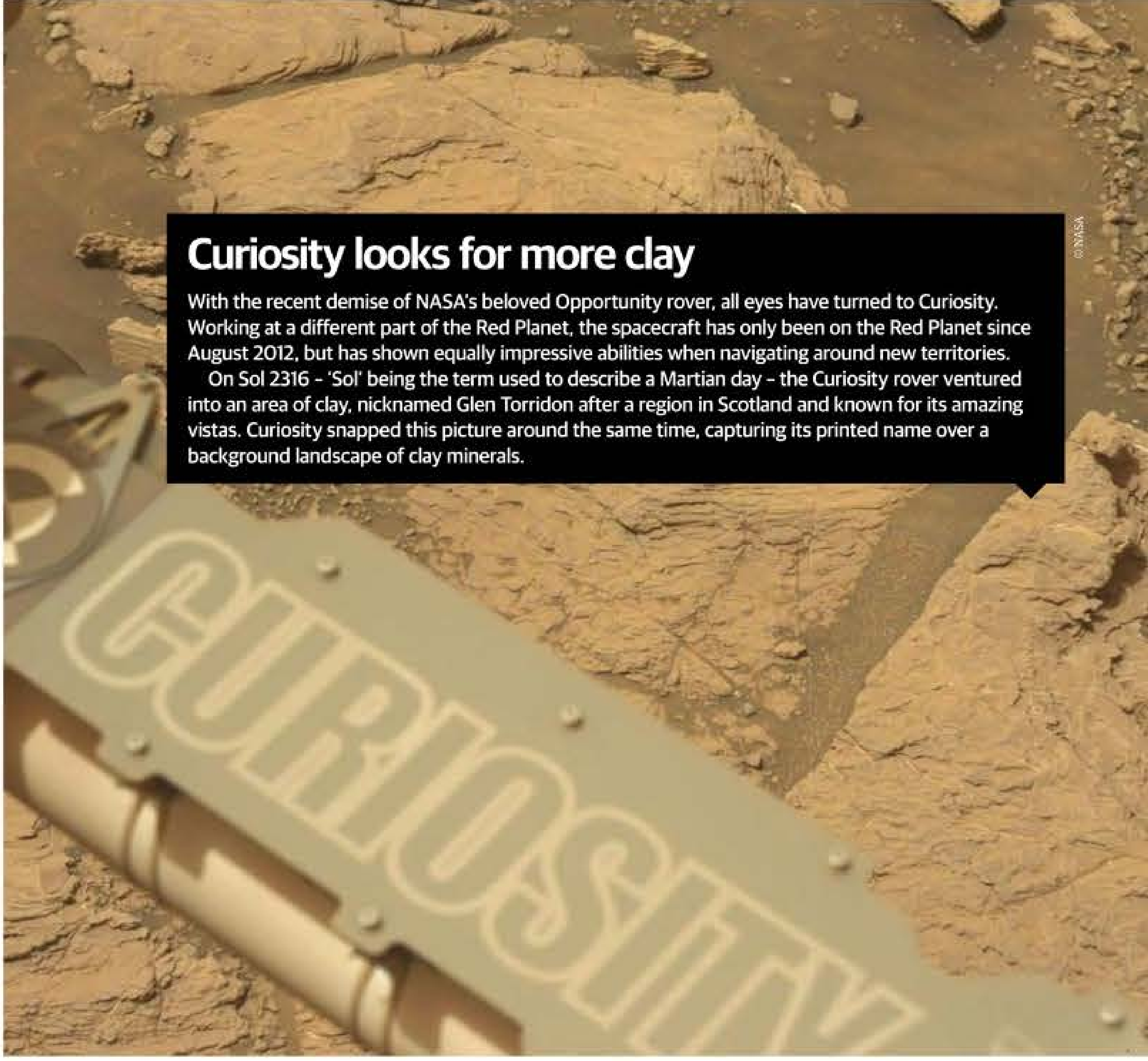

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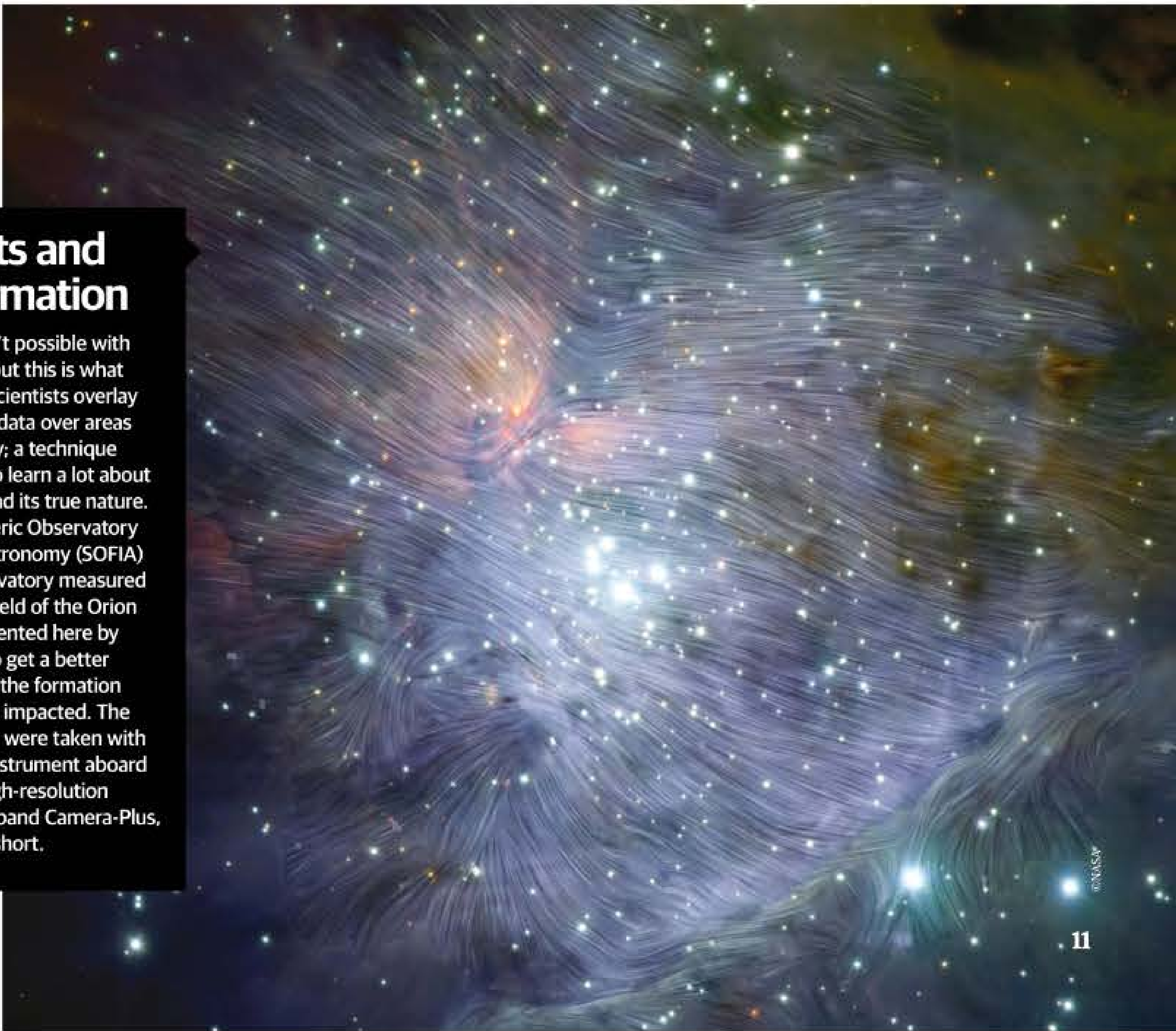
Curiosity looks for more clay

With the recent demise of NASA's beloved Opportunity rover, all eyes have turned to Curiosity. Working at a different part of the Red Planet, the spacecraft has only been on the Red Planet since August 2012, but has shown equally impressive abilities when navigating around new territories.

On Sol 2316 – 'Sol' being the term used to describe a Martian day – the Curiosity rover ventured into an area of clay, nicknamed Glen Torridon after a region in Scotland and known for its amazing vistas. Curiosity snapped this picture around the same time, capturing its printed name over a background landscape of clay minerals.



© NASA

Magnets and star formation

A sight that isn't possible with human eyes - but this is what we see when scientists overlay magnetic field data over areas of the night sky; a technique that helps us to learn a lot about the universe and its true nature. The Stratospheric Observatory for Infrared Astronomy (SOFIA) airborne observatory measured the magnetic field of the Orion Nebula, represented here by stream lines, to get a better picture of how the formation of baby stars is impacted. The measurements were taken with a brand-new instrument aboard SOFIA - the High-resolution Airborne Wideband Camera-Plus, or HAWC+ for short.

SpaceX's Crew Dragon docks at Space Station for first time

Words by **Mike Wall**

SpaceX's new astronaut taxi just checked off another huge milestone on its maiden orbital flight. The Crew Dragon capsule successfully docked with the International Space Station on 3 March at 10:51am GMT (5:51am EST), about 27 hours after launching into orbit from NASA's Kennedy Space Center (KSC) on Florida's Space Coast. Dragon linked up with a docking port on the station's Harmony module as the two craft sailed 402 kilometres (250 miles) over the Pacific Ocean, just north of New Zealand.

"Congratulations to all the teams on a successful docking," NASA astronaut Anne McClain radioed Mission Control from aboard the space station. She and her Expedition 58 crewmates David Saint-Jacques of Canada and Oleg Kononenko of Russia followed the docking closely.

Applause broke out at SpaceX's control centre in Hawthorne, California, as Crew Dragon secured itself to the station with a set of hooks and latches. At 13:07pm GMT (8:07am EST) the station crew opened the hatch to Crew Dragon for the first time and floated inside, with SpaceX beaming live views of the capsule's interior where the dummy astronaut Ripley and a Celestial Buddies Earth plush toy awaited the astronauts.

"Everything looks great," McClain told Mission Control after looking inside Crew Dragon through a hatch window just before the crew entered. "Ripley and Earth both look like they enjoyed their trip up here."

Crew Dragon will spend the next five days attached to the orbiting lab, eventually ending its uncrewed shakeout cruise, which is known as Demo-1, with a parachute-aided splashdown in the Atlantic Ocean on the morning of Friday 8 March.

The spacecraft docked itself at the space station in a first for SpaceX, whose cargo-only versions of the Dragon spacecraft had to be captured by a robotic arm controlled by astronauts and then attached to the station. Crew Dragon docked itself at a new parking spot on the station called an International Docking Adapter.

"This is unbelievable news for everyone here at SpaceX and at NASA," SpaceX software engineer Tom Praderio said during live NASA TV commentary from SpaceX's mission control centre.

NASA astronaut Bob Behnken, who will fly on Demo-2 – the first Crew Dragon mission to carry humans – later this year, watched the docking in SpaceX's control centre with his future crewmate Doug Hurley.

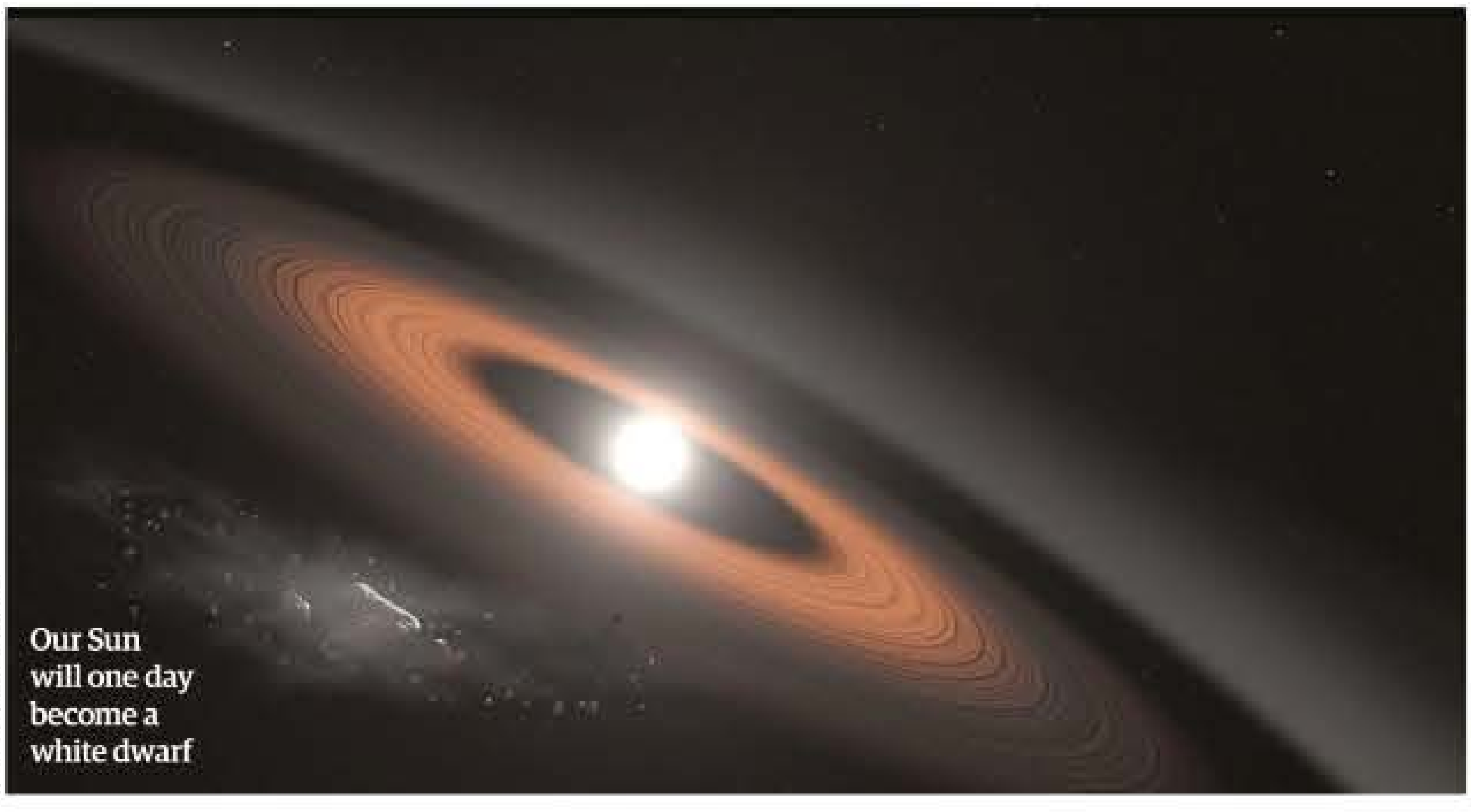
"It was just super-exciting to see it," Behnken said on NASA TV. "Just one more milestone that gets us ready for our flight coming up here."

White dwarf star with weird rings is spotted by 'backyard' sleuths

Words by **Meghan Bartels**

Astronomers have spotted a puzzlingly old, dusty white dwarf star, the remains of a star like our own Sun, and they think the structure may change their understanding of how white dwarfs influence their environments.

The star, known as LSPM J0207+3331, seems to be by far the oldest known white dwarf surrounded by a dusty disc. And if observations hold up it will be the first white dwarf scientists know of that sports multiple dust rings within that disc, as their current theory suggests.



Our Sun will one day become a white dwarf

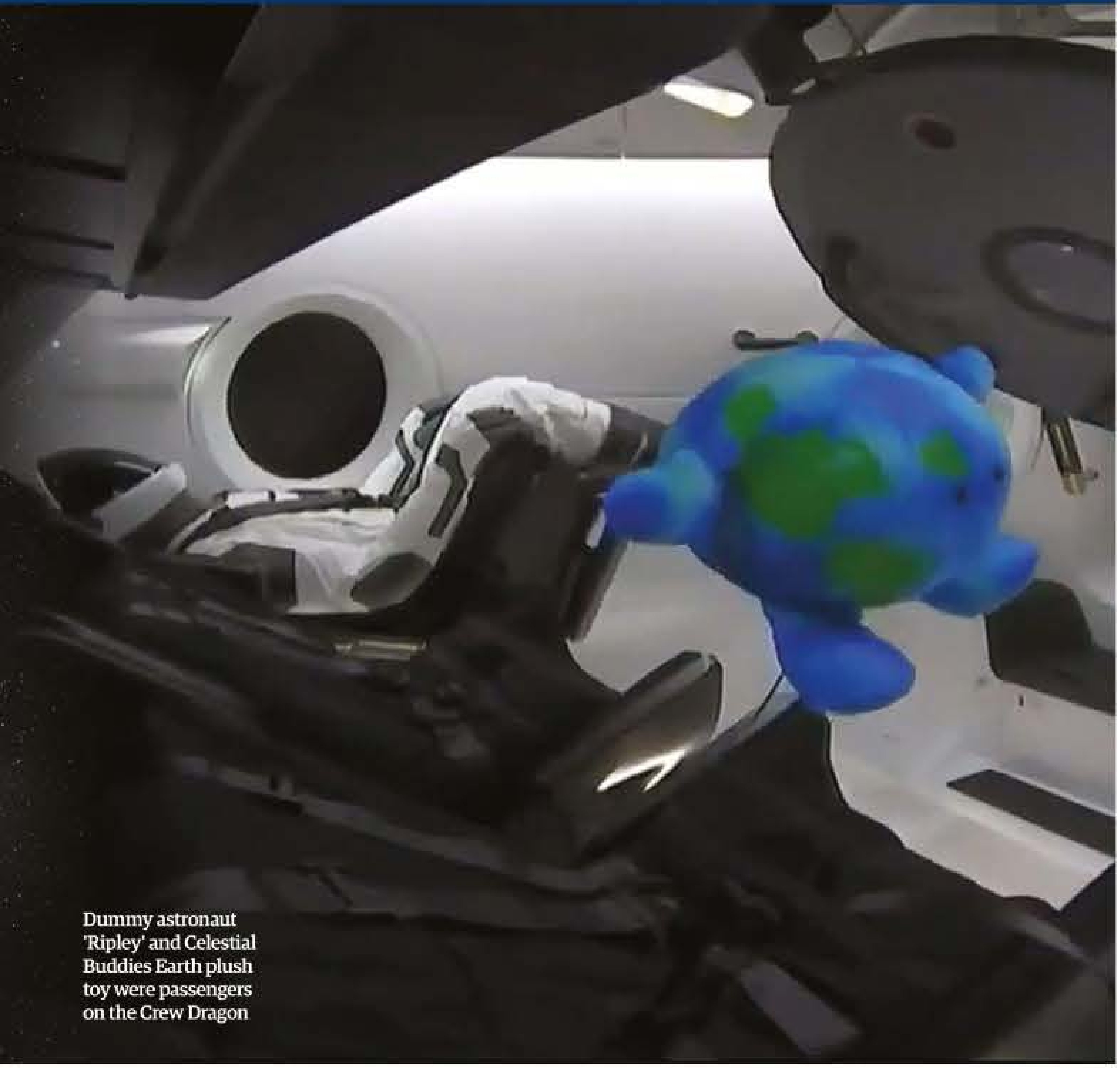
© NASA; NASA TV; SpaceX

"This white dwarf is so old that whatever process is feeding material into its rings must operate on billion-year timescales," John Debes, a co-author on the new research and an astronomer at the Space Telescope Science Institute, said in a statement. "Most of the models scientists have created to explain rings around white dwarfs only work well up to around 100 million years, so this star is really challenging our assumptions of how planetary systems evolve."

Finding white dwarfs surrounded by stuff isn't unusual, since these stars are the dense corpses of Sun-like stars that have shed their gas. But typically these former suns end up absorbing the solar system rubble that surrounds them.

And the team believes that this white dwarf is about 3 billion years old – which would be nearly three-times older than the previous record holder for an ancient, ringed white dwarf. That age suggests that some sort of process would need to be refilling the rings, and scientists aren't sure yet what that process could be.

The star's weirdness was discovered through a volunteer science project based out of NASA's Goddard Spaceflight Center called Backyard Worlds, which is based on infrared data.



Dummy astronaut 'Ripley' and Celestial Buddies Earth plush toy were passengers on the Crew Dragon

Planet Nine likely to be found within a decade

Words by **Mike Wall**

Planet Nine will probably be detected within a decade or so, if the putative world does indeed exist, a new study suggests. Three years ago Caltech astronomers Konstantin Batygin and Mike Brown estimated that the hypothesised Planet Nine - also known as Planet X, Giant Planet Five or Planet Next - is perhaps ten-times more massive than Earth and lopes around the Sun at an average distance of 600 astronomical units (AU) - one AU is the Earth-Sun distance, about 150 million kilometres (93 million miles).

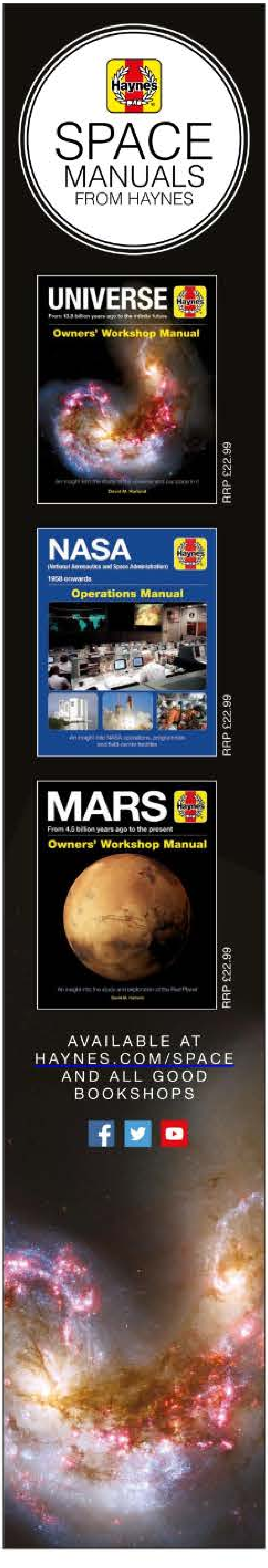
But in a detailed and lengthy new review paper Batygin, Brown and two other researchers determined that the putative planet is likely smaller and less far-flung than that.

Observational evidence and computer-modelling work indicate that ten Earth masses is an upper limit for Planet Nine, according to the new study. Indeed, five Earth masses and an average orbital distance of 400 to 500 AU are likely to be closer to the actual marks, the scientists found. And that means Planet Nine is probably easier to spot than scientists had suspected.

"Perhaps counterintuitively, the increase in brightness due to a smaller heliocentric distance more than makes up for the decrease in brightness due to a slightly diminished physical radius, suggesting that Planet Nine is more readily discoverable by conventional optical surveys than previously thought," Batygin and his colleagues wrote in the paper.

The Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) project in Hawaii could conceivably spy Planet Nine any day now. And even if the hypothesised world is on the fainter and more distant side, it will probably still be detectable by the Large Synoptic Survey Telescope, scheduled to come online in Chile in the early 2020s, the researchers said.

We're closer to detecting Planet Nine



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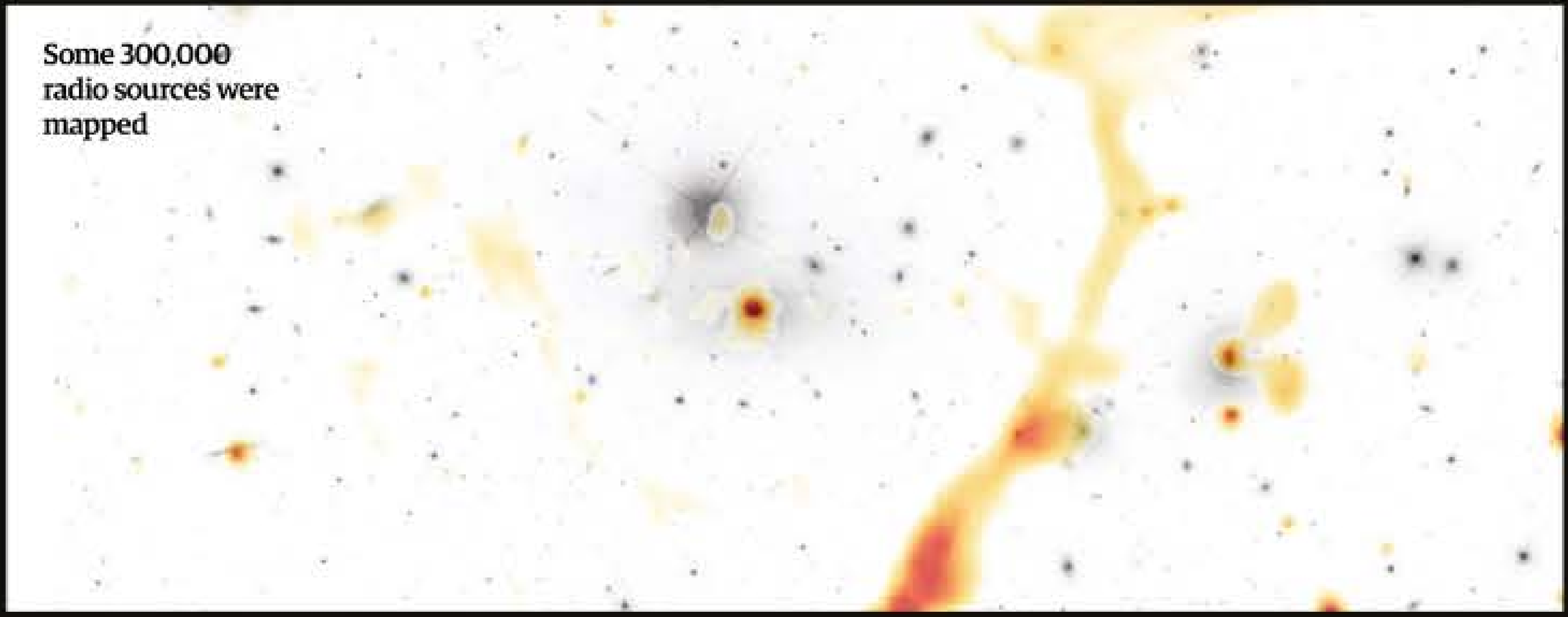

Some 300,000 radio sources were mapped

Scientists hit cosmic jackpot with discovery of 300,000 galaxies

Words by **Mike Wall**

Astronomers have spotted thousands of previously unknown galaxies, a raft of new studies reports. The huge data haul should help researchers better understand the birth and growth of supermassive black holes, the evolution of galaxy cluster mergers and many other cosmic phenomena, discovery team members said.

The team consists of more than 200 astronomers from 18 countries who pored over results from the first part of a sky survey performed by the Low Frequency Array (LOFAR), a network of radio telescopes operated by the Netherlands Institute for Radio Astronomy (ASTRON). Most LOFAR 'scopes are in the Netherlands, but the system spans multiple European countries including Germany, France and the United Kingdom.

The researchers discovered and mapped 300,000 radio sources, nearly all of which, the scientists said, are extremely distant galaxies. These detected radio emissions are dominated by fast-moving jets of material rocketing away from the supermassive black holes at these galaxies' hearts.

"LOFAR has a remarkable sensitivity, and that allows us to see that these jets are present in all of the most massive galaxies, which means that their black holes never stop eating," team member Philip Best, of the University of Edinburgh in Scotland, said in a statement. "With LOFAR, we hope to answer the question: 'Where do those black holes come from?'" team member Huub Röttgering, of Leiden University in the Netherlands, said in the same statement.

The new studies cover only the first two per cent of the sky survey, LOFAR team members explained. When complete, they added, the project should map a total of 15 million cosmic radio sources.

Water on Mars may have been triggered by meteorite impacts

Words by **Charles Q. Choi**

Cosmic impacts on young Mars may have triggered deluges, potentially explaining why the Red Planet was once covered in water, a new study finds. Although Mars is now cold and dry, scientists have for decades found evidence suggesting that the planet's surface was once covered with rivers, streams, ponds, lakes and perhaps even seas and oceans. Since there is life virtually everywhere on Earth where there is water, this history of water on the Red Planet raises the possibility that Mars was once home to life, and might host it still.

However, despite the evidence for Red Planet water, scientists haven't been able to figure out how Mars could have possessed this water during its early days. During the Red Planet's youth the Sun was cooler than it is now, and previous climate models suggested that Mars may have lacked enough greenhouse gases to trap enough heat to generate significant amounts of rainfall.

The researchers focused on impacts from the largest rocks to ever hit Mars and found that one of those impacts would make the atmosphere so hot that, for about half a Martian year, water would be unable to last on the Martian surface. After that, constant rain would fall for about a dozen Martian years. During this time the water that was initially vaporised by the collision would return as deluges, flooding the Red Planet with an average of about 2.6 metres (8.5 feet) of water covering Mars per Earth year.

Virgin Galactic reaches space again, flies test passenger for first time

Words by **Meghan Bartels**

In its first flight with a test passenger on board, Virgin Galactic's SpaceShipTwo VSS Unity flew into the Mojave sunrise on 22 February and soared to an altitude of 89.9 kilometres (55.87 miles), just two months after its first flight to space.

WhiteKnightTwo, the plane that lifts VSS Unity high enough to fire its motor, took off from the Mojave Air and Space Port launch site in California. Unity separated about an hour into the flight, then fired its motor.

VSS Unity reached a top speed of Mach 3.0 and reached a maximum altitude seven kilometres (4.4 miles) higher than Virgin Galactic's historic 13 December flight.

On board the flight were copilots Dave Mackay and Michael Masucci, each of whom has clocked more than 10,000 hours in the air. A third Virgin Galactic staff member, Beth Moses, who is the company's chief astronaut instructor, was also aboard. Moses was on board to provide more data about how human bodies experience SpaceShipTwo flights and what the in-cabin experience is like for passengers.

The flight also carried four payloads provided by NASA. Those experiments will provide scientists with data about the implications of microgravity on how liquids and gases interact, how payloads vibrate and how dust particles behave, as well as testing electromagnetic field sensor equipment.

Chief astronaut instructor Beth Moses enjoys the view

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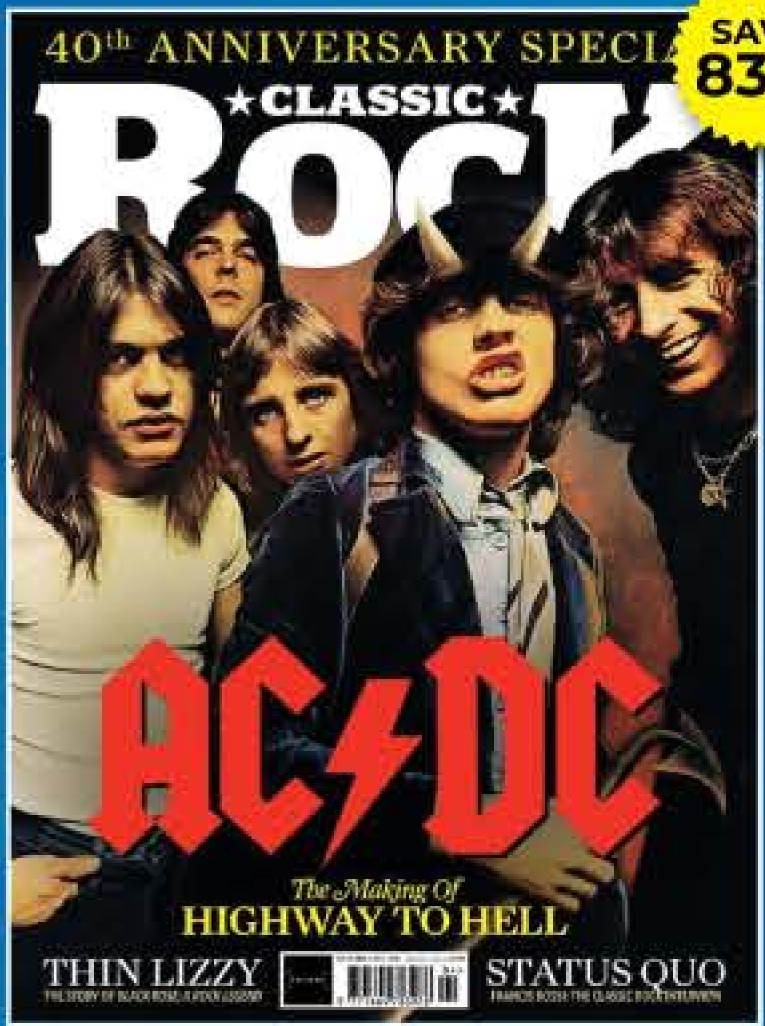

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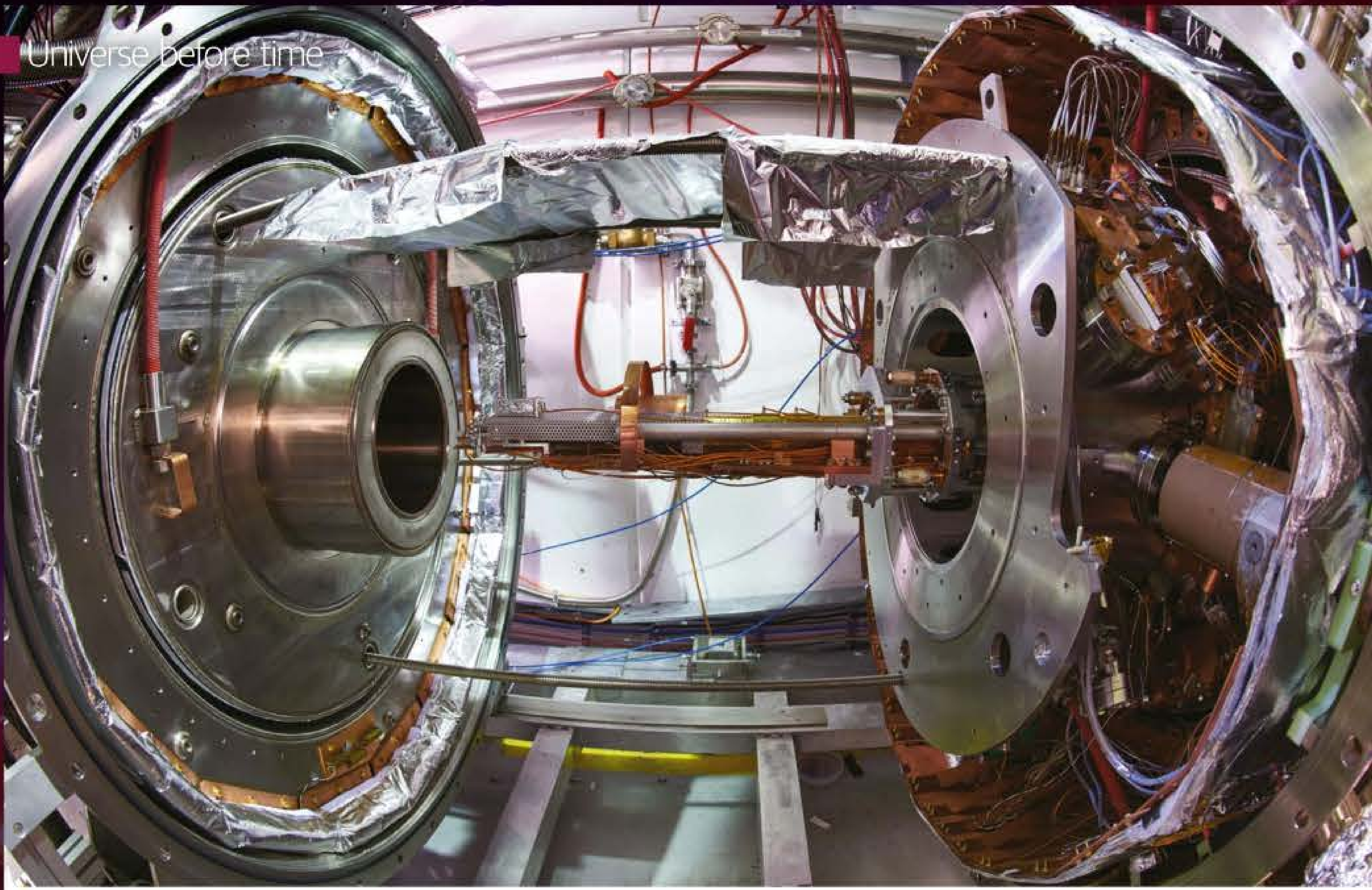
ERSE RE TIME

Could the existence of a mirror-image cosmos before the Big Bang solve some of the biggest mysteries in astronomy?

Reported by Giles Sparrow



Our universe encompasses everything around us, from the smallest subatomic particle to the largest and most distant galaxy supercluster. Its laws of physics control every possible interaction from the gravitational attraction that keeps planets in orbit around the Sun to the complex chemistry that gives rise to life; it's hard for us to imagine it being any other way.

But for astronomers and physicists there are still some big questions about why the universe is the way it is. One of the most famous is the mystery of elusive dark matter - the missing five-sixths of the universe's mass that only makes its presence felt through the influence of its gravity. Another is the dominance of a certain set of subatomic particles in the universe - the familiar ones such as electrons, protons and neutrons that we call 'matter' - when there was nothing in the Big Bang itself to prevent the formation of equal amounts of 'antimatter'.

But a new theory developed by two Canadian physicists suggests a radical new way of looking at the universe, along the way offering solutions to these and other major questions. According to Neil Turok and Latham Boyle of the Perimeter Institute for Theoretical Physics in Waterloo, Canada, we may be looking at one aspect of a universe of two halves.

Boyle and Turok's theory, developed with Kieran Finn, now a PhD student at the University of Manchester, originates from questions of symmetry - a concept familiar to most of us from school geometry, but which scientists use in a more expansive, fundamental sense. In physics, a symmetric process is one that produces the same result if the values of one or more properties involved are flipped or reversed. A process such as a simple interaction between particles may be symmetric under different transformations of this kind and, as a broad rule of thumb, as structures become more complex they become less symmetric.

"The way Neil and I were thinking about it is, if you imagine a cartoon picture of the expanding universe, we're at the top of a sort of expanding cone, 14 billion years after the Big Bang," explains Boyle. "We can see back in time with astronomical observations [thanks to the travel time taken for light to reach Earth from distant parts of the universe] but not all the way back to the Bang. What we see is there is a remarkably symmetric universe with very simple properties compared to the universe today. Those simple properties are the fundamental puzzle that early universe cosmologists want to explain - that very special initial state is clearly offering some very important clues as to what was happening in the early universe and how the universe was born. The question is, what is it trying to tell us?"

The traditional explanation for the origin of the relatively simple early universe is a hypothetical event known as inflation - a short-lived burst of violent expansion triggered a fraction of a second after the Big Bang itself in which the universe would have grown far faster than the speed of light. The process, it's claimed, blew up a tiny pocket of the chaotic early universe created by the Big Bang itself into the entire cosmos we see today. This 'smoothed out' conditions in general while magnifying submicroscopic energy fluctuations into the seeds of today's galaxy clusters and superclusters.

© NASA, ESA; CERN; Christopher Michel; Orlando Florin Rosu / Alamy Stock Photo

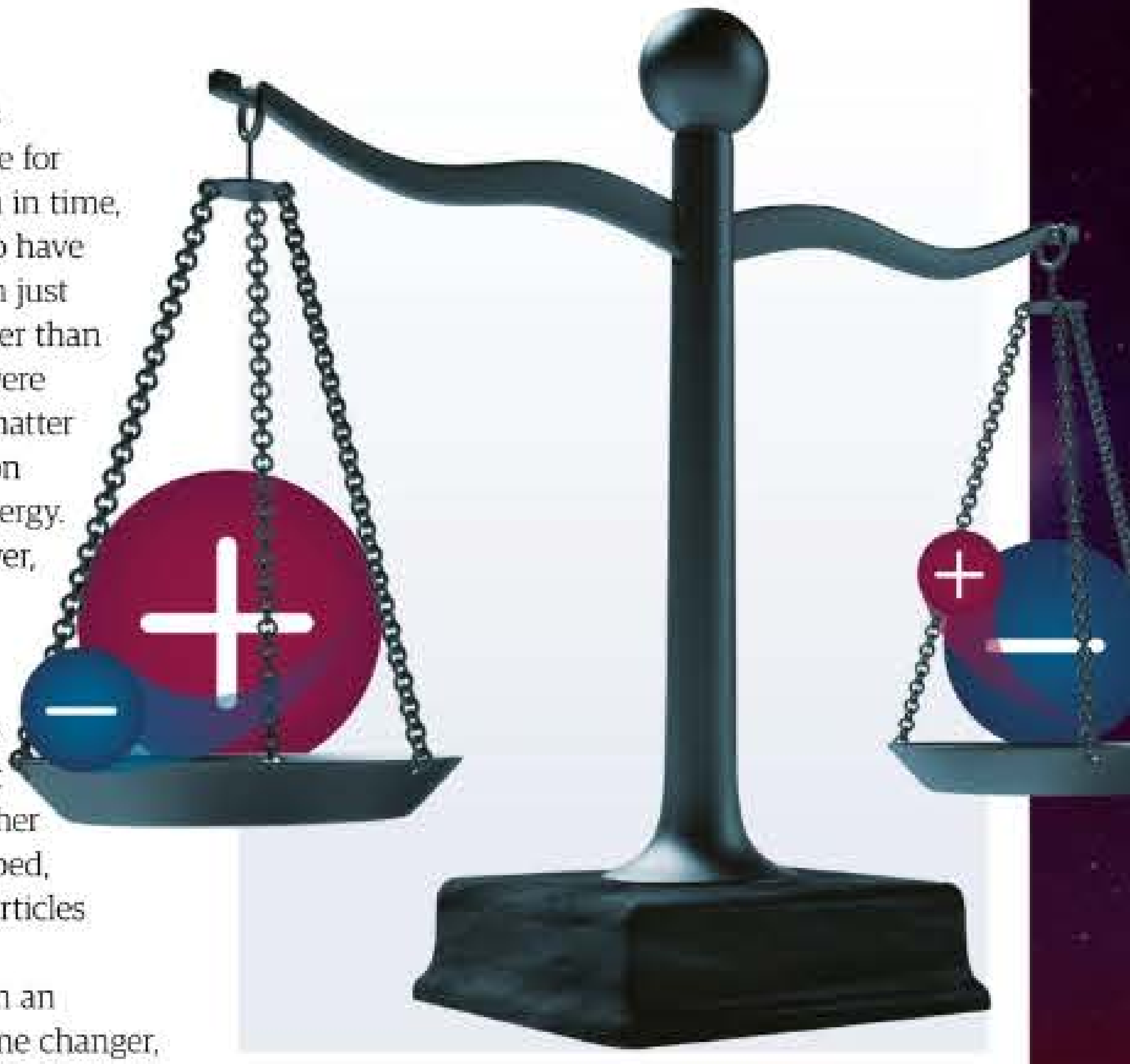
The Canadian researchers, however, are suggesting a different picture that does away with the inflationary era: "If you follow the expanding universe back even further," continues Boyle, "then things collapse into a singularity [a point of infinite density and zero volume where the normal equations describing space and time cease to apply]. Ordinarily that's a mess, and you can't follow the solution beyond that. But we noticed that because of the special properties of the initial state you actually can continue to follow it back, and you get this solution that extends back. In addition to our usual universe expanding from the Big Bang, the solution has a second part which extends backwards in time from the Big Bang. And moreover we noticed it has a property that if you flip it in time you can also reflect the two parts into each other – the part before the Bang is like a symmetric mirror image of the part after the Bang."

One thing about this new discovery that immediately caught the researchers' eyes was how it seemed to echo a long-standing cosmological niggle one might call the CPT reversal symmetry puzzle. CPT stands for charge, parity and time – a combination of three distinct types of symmetry. CPT symmetry seems fundamental to the laws of physics – when looking at any physical process you can find an equally correct process by reversing the charges of the particles involved, effectively replacing them with their antimatter equivalents; reflecting their positions in a mirror – so-called 'parity' transformation – and running time backwards.

But despite there being nothing in its fundamental laws to dictate a preference for matter particles or a particular direction in time, the universe we see around us seems to have other ideas. Time very definitely runs in just one direction, and there's far more matter than antimatter; just as well for us – if they were equally balanced then matter and antimatter particles would 'annihilate' each other on contact, self-destructing in a burst of energy.

Boyle and Turok's new model, however, offers a simple and intuitive solution to the mystery. "Once we realised that we weren't looking at the whole solution we found that the full solution could be symmetric, as we would expect." To put it simply, in the anti-universe on the 'other side' of the Big Bang, directions are flipped, time runs backwards and antimatter particles are dominant.

What transforms the new model from an intriguing "what if?" into a potential game changer,



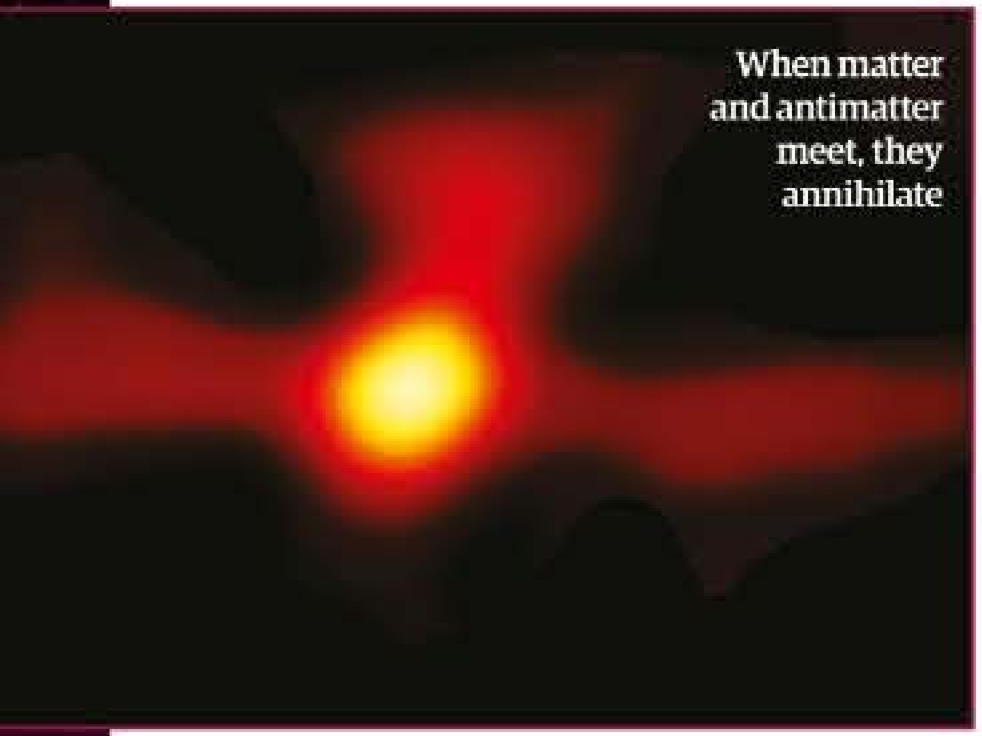
"That initial state is clearly offering some very important clues as to what was happening in the early universe" **Latham Boyle**

Top left: Physicists use the huge machines at the European Organization for Nuclear Research (CERN) in Switzerland to generate and store antimatter for experiments

Left: Our universe consists of countless galaxies

Bottom left: Dark matter only gives away its presence through effects such as gravitational lensing

Right: The Keck Array experiment in Antarctica



When matter and antimatter meet, they annihilate

> "The part before the Bang is like a symmetric mirror image of the part after the Bang"
>
> **Latham Boyle**

however, are the consequences arising out of it. "These clues in the early universe seem to be a hint that we can extrapolate in a fairly simple way," continues Boyle. "So we elevated that to a principle: if we take the idea that the universe is CPT symmetric as a starting point, then where does that lead us? One of the things we're most excited about with this interpretation is that it gives new explanations for certain things that we've already observed about the universe but maybe don't yet have satisfying explanations for, and it also makes a couple of predictions for things we might observe in future experiments."

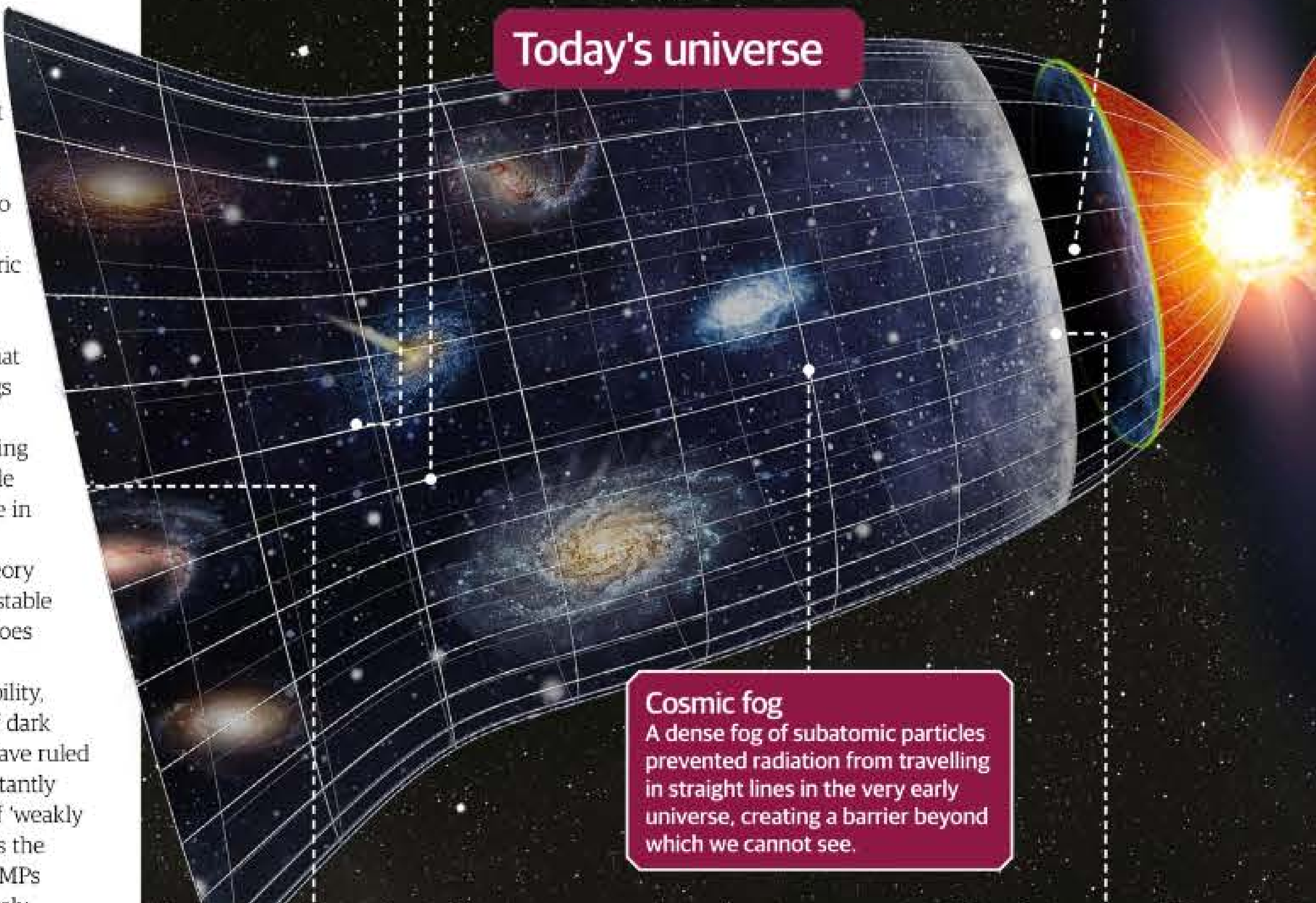
This is the acid test of any scientific theory - can it explain observations and make testable predictions - so just what consequences does the CPT-symmetric model predict?

One of the most intriguing is the possibility, at long last, of a solution to the mystery of dark matter. Since astronomical observations have ruled out other ideas, most physicists now reluctantly fall back on the loosely defined concept of 'weakly interacting massive particles' or WIMPs, as the source of the universe's missing mass. WIMPs could be almost anything - the name merely describes their basic properties of a substantial mass and an immunity to interactions with normal matter - and most potential WIMP candidates are so-called exotic particles whose existence relies on the existence of hitherto unidentified physical processes, and possibly further unidentified particles.

Boyle and Turok's theory, however, offers a simpler option, arising from its unique shift of perspective. The so-called Standard Model of particle physics includes not only the familiar

The other universe

A symmetric universe theory conjures up an entire cosmos with equal and opposite properties to our own



First atoms
About 400,000 years after the Big Bang, subatomic matter particles coalesced into atoms, mostly of hydrogen. This cleared the fog and allowed trapped radiation to escape across space.

Looking back in time
The limited speed of light means that we see distant parts of space as they were long ago, turning the universe into a cosmic time machine.

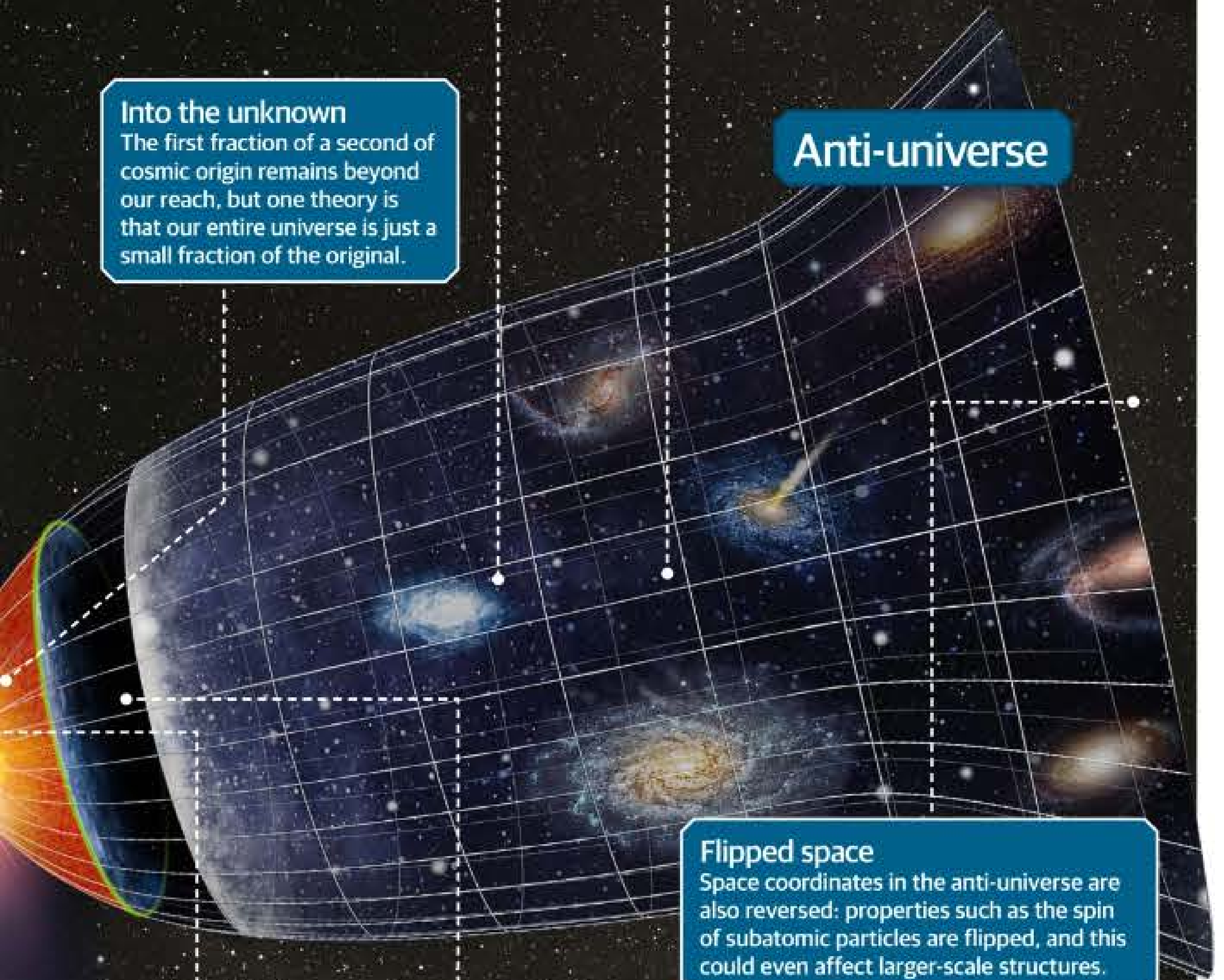
A universe of matter
Our universe is dominated by matter - the family of Standard Model particles that includes the positively charged proton and negatively charged electron.

Cosmic fog
A dense fog of subatomic particles prevented radiation from travelling in straight lines in the very early universe, creating a barrier beyond which we cannot see.

Today's universe
Present-day universe with complex structures separated by large gaps in space but a broadly uniform structure on the very largest scales.

Early era
Particle accelerators can collide particles with energies approaching those of the early universe, allowing physicists to map the way in which the first matter particles formed.

© NASA; Nicholas Forder



Reversed time
In the anti-universe time preferably runs 'backwards' from our point of view. But since the laws of physics operate in the same direction, residents of the anti-universe might not perceive anything different.

Dominant antimatter
The anti-universe is dominated by antimatter particles – antiprotons with negative charge and positrons, the positive equivalent of electrons.

Into the unknown
The first fraction of a second of cosmic origin remains beyond our reach, but one theory is that our entire universe is just a small fraction of the original.

Flipped space
Space coordinates in the anti-universe are also reversed: properties such as the spin of subatomic particles are flipped, and this could even affect larger-scale structures.

The backwards universe
A new theory suggests that instead of originating in a singularity, our universe is actually balanced by a mirror-image cosmos expanding backwards in time 'before' the Big Bang.

Singularity?
Traditional cosmology envisages space, time and all the energy in the universe erupting from a single superdense point called a singularity – an event that cannot be described with normal mathematics.

matter particles such as protons, neutrons and electrons, but also a handful of mysterious 'neutrinos' that are generated by processes such as nuclear fusion in the heart of stars. Three types of neutrino have been confirmed by physicists, and all three are 'left-handed' – a distinction relating to the way that their spin or rotation is always oriented in the opposite sense to their motion.

Boyle picks up the story: "We think that in addition to those three left-handed neutrinos there should be three right-handed neutrinos, and there are already some good theoretical reasons and experimental hints that these particles can exist. A right-handed neutrino is the only near-Standard Model particle whose predicted properties allow it to live for the age of the universe and which would be otherwise undetectable."

A right-handed neutrino with substantial mass might seem like an ideal candidate for dark matter – so why is it generally overlooked by cosmologists?

"The reason you don't hear more about these particles is they're usually regarded as difficult to produce in the early universe," explains Boyle. "You clearly have to make enough of these particles to produce the dark matter we see today, but in the same conditions where this particle becomes stable enough to survive, it simultaneously doesn't get produced – it stops talking to and interacting with all the other particles, so in theory it doesn't get made."

A CPT-symmetric universe, however, changes the ground rules. The reasons are complex, but in essence the idea is that the symmetric universe's 'vacuum state' – the configuration of space-time with no particles and the lowest possible energy – is different from the one we perceive in the non-symmetric universe we can see, and this mismatch gives rise to the possibility of plentiful right-handed neutrinos. "It's analogous to Stephen Hawking's famous discovery of Hawking radiation," points

Living in an anti-universe

If the anti-universe exists, what would conditions inside it be like?

What would an antimatter universe look like?
There's no reason a universe much like our own couldn't form out of the antimatter versions of particles in the Standard Model. Physicists have been making atoms of antihydrogen since the 1990s, and this would be the dominant component of the anti-universe, just as hydrogen is the dominant element in ours. One big question is whether gravity affects matter and antimatter in the same way – most think it should, but experiments to confirm this are only just becoming practical.

Could there be anti-life?
Assuming gravity pulls antimatter together in the same way as normal matter, the anti-universe should have its own stars and planets that could give rise to their own complex chemistry and, eventually, life. In fact, a strict interpretation of CPT symmetry would imply that the anti-universe is a genuine mirror image of our own, with antimatter versions of Earth and its population.

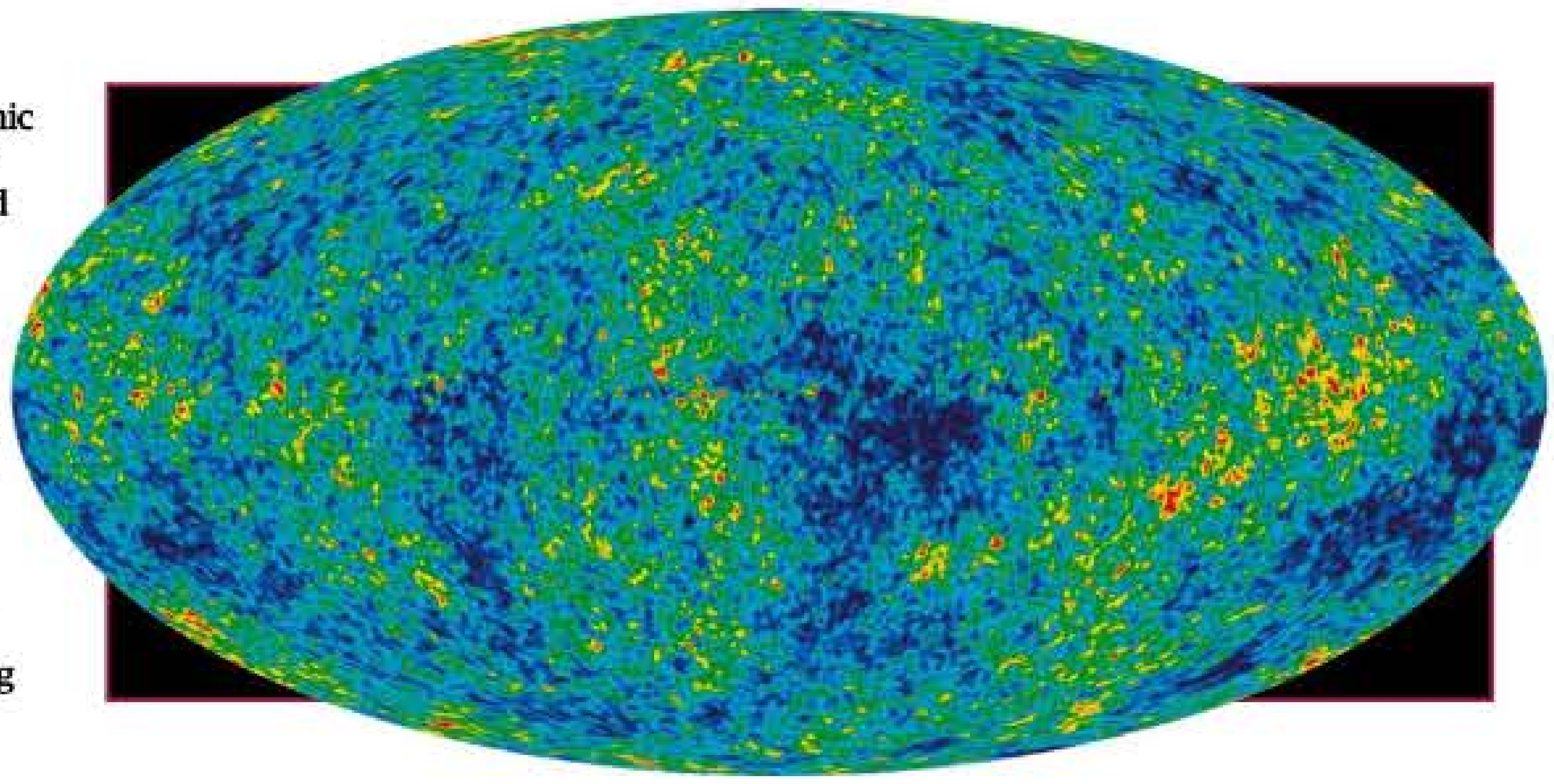
How would time flow?
Although time in the anti-universe would run in the opposite direction from our point of view, its inhabitants wouldn't be aware of anything unusual. The laws of thermodynamics, which loosely define the 'arrow of time' and the direction in which things tend to break down into chaos, would flow in the opposite direction, and so would everything else. If we could observe the anti-universe from 'outside' we would see it as a strange place in which structure evolved backwards in time, but from inside things would appear just the same – from the point of view of an anti-cosmologist, our universe would be the one in which time flows backwards!

out Boyle. "He said that a black hole is really in one state, but an observer far away defines a different vacuum state, so they see particles being emitted from the black hole. The same thing happens for us – the universe and the Big Bang at its beginning are really in the CPT-symmetric state, but a present-day observer far away from the Big Bang defines a different state. So we should find these neutrinos being radiated from the Big Bang in much the same way as particles radiate from a black hole."

The new theory even allows Turok and Boyle to estimate the mass of the dark-matter neutrino at a billion-times the mass of a proton. This in turn allows them to calculate the energy of particles emitted if the neutrino occasionally disintegrates or decays into particles of more easily detected matter – but what if that doesn't happen?

"Fortunately we also predict other things that we can measure and which will be tested with future experiments," says Boyle reassuringly. "For example, we still have difficulty measuring the masses of the light neutrinos that we know about, and our theory predicts that the lightest of the light neutrinos will be exactly massless. Various experiments are going after that measurement, and cosmological measurements in particular are pushing the sum of the three light neutrino masses down towards its lowest possible limit. If our prediction turns out to be wrong, then the sum of the neutrino masses is higher than we predict, and they should detect that pretty soon.

"Another prediction is that there should be no primordial gravitational waves [ripples in the space-time fabric of the universe created when huge masses interact in certain ways]. Current detectors have measured 'late-universe' gravitational waves created when two black holes or neutron stars collide and merge into one, but was the universe also born with some gravitational waves present? There are competing models that predict whether such waves could be present, but ours says no. We think that as experiments become better, they'll still not find evidence for these gravitational waves."



Right: Cosmic Microwave Background Radiation (CMBR) offers the furthest and earliest view of our universe, about 400,000 years after the Big Bang

Promising though it is, the new idea is in its infancy, and while it offers intriguing explanations for some unexplained aspects of the universe, there are others where it cannot yet match the long-established inflation model, as Boyle freely admits. "One very important thing that we do not yet claim to explain is the 'power spectrum' of the primordial density perturbations [how the strength of the ripples change with their length]. Another is why, if you ignore the perturbations, the very large-scale structure of the universe is both homogeneous and isotropic – in other words it looks the same in every direction and it looks the same if you move through it in some direction in space. The original papers we put out just took that for granted, but we do have something in the works that we hope will give an explanation for this."

Perhaps the most appealing aspect of the theory, though, is its elegant simplicity – unlike some other cosmological models it doesn't require unseen dimensions beyond the familiar ones of space and time, and neither does it call for a host of new particles beyond those already known or suspected to exist in the Standard Model. "In that sense it gives a very minimal description of the cosmos," reflects Boyle. All it takes is an anti-universe.

> "It gives new explanations for certain things that we've already observed about the universe" **Latham Boyle**

Evidence for a backwards universe

No waves – so far!

In some models of the inflation process, cosmologists predict that powerful space-time ripples called gravitational waves should have been produced, but so far there's no sign of them being detected. A CPT-symmetric universe would produce no such waves.

The dominance of matter

If the universe we see is all there is, then another question arises – why is it made of matter rather than an equal mix of matter and antimatter when the Big Bang should have created both in equal amounts?

The arrow of time

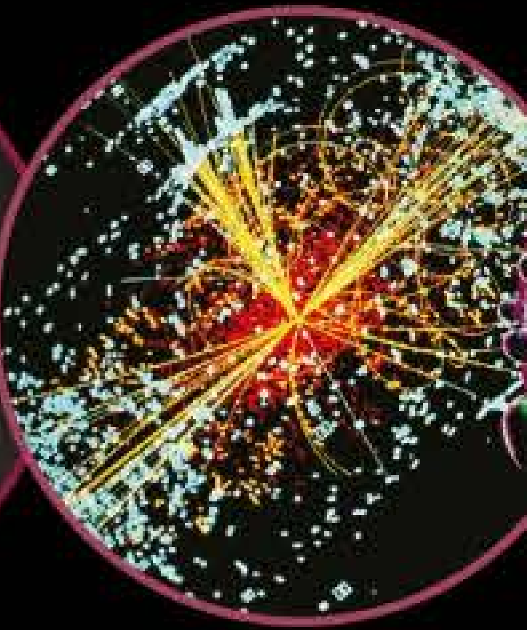
Despite CPT symmetry, however, the universe as a whole shows a marked preference for time to flow in a single direction – for example, eggs smash if they are dropped, but never spontaneously reassemble themselves if the fragments are dropped again.

CPT symmetry

The laws of physics seem to obey a fundamental rule called CPT symmetry: if a particular subatomic process is possible, then a mirror-image process in which electric charges are flipped and coordinates of space and time are reversed can also happen.

Dark matter

Invisible dark matter seems to account for 85 per cent of mass in the universe. The CPT-symmetric theory suggests the dark matter could be relatively simple particles called 'right-handed neutrinos', which are ruled out in more traditional views of the cosmos.



How we'd get to another universe?

Travelling to another universe lies well beyond the limitations of current physics and technology, but how might we do it?

Time travel

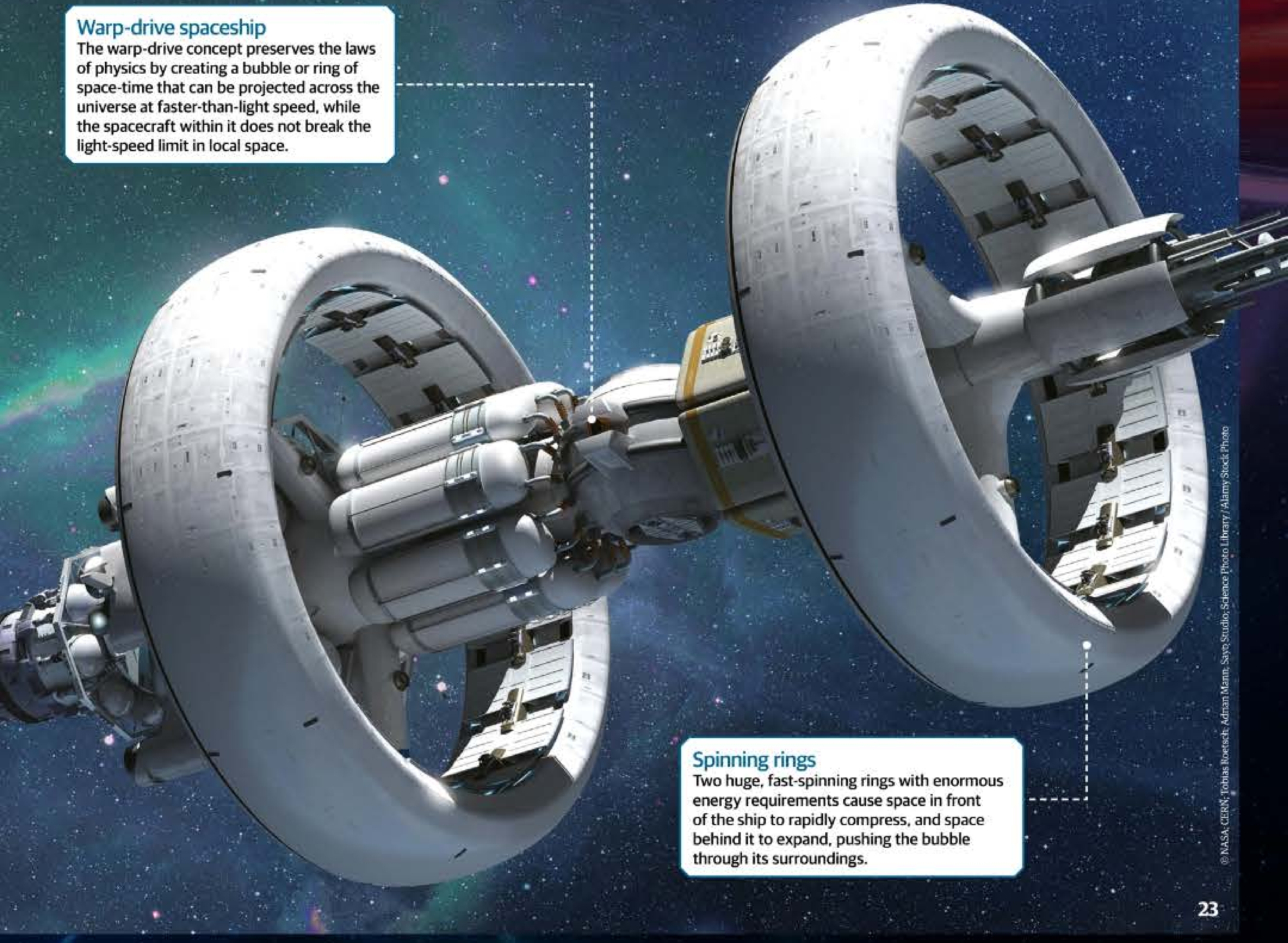
One way of reaching the CPT-symmetric anti-universe would require travelling backwards in time, past the Big Bang and surviving in a realm of antimatter without being instantly annihilated. Powerful magnetic fields can be used to keep matter and antimatter apart from each other.

Wormholes

These hypothetical short-cut passages through space and time look like black holes at either end, but lack the deadly singularity in the middle. Wormholes might exist naturally or be manufactured by advanced civilisations, but they would only be useful for hopping around 'our' universe – they could never link the anti-universe.

Interstellar travel

Our universe extends far beyond the limits of what we can see, and may be effectively infinite. That would mean a multitude of other 'observable universes' beyond our own, theoretically reachable by faster-than-light interstellar travel. But again, this wouldn't be a way of reaching the anti-universe.



Warp-drive spaceship

The warp-drive concept preserves the laws of physics by creating a bubble or ring of space-time that can be projected across the universe at faster-than-light speed, while the spacecraft within it does not break the light-speed limit in local space.

Spinning rings

Two huge, fast-spinning rings with enormous energy requirements cause space in front of the ship to rapidly compress, and space behind it to expand, pushing the bubble through its surroundings.

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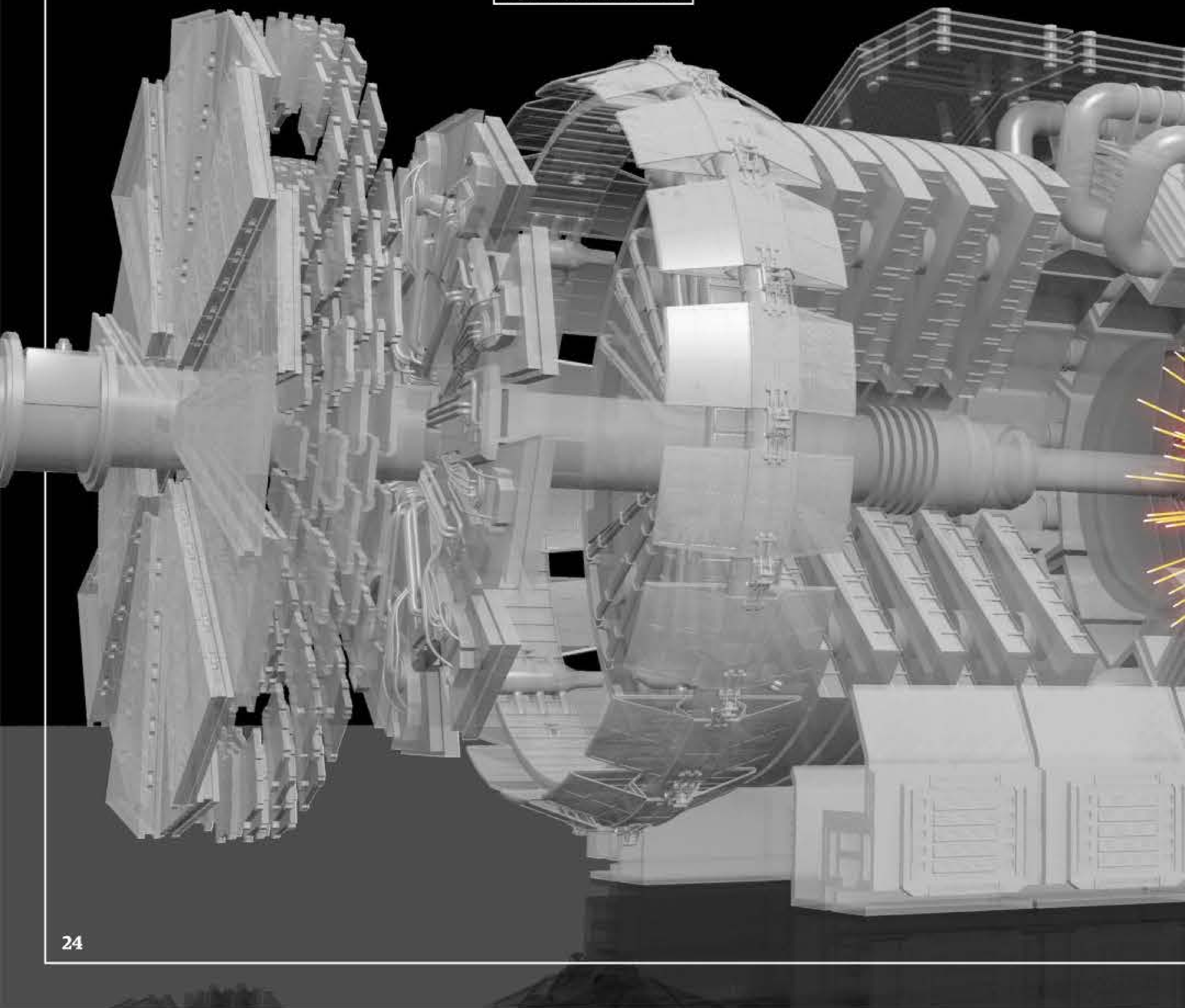
FUTURE CIRCULAR COLLIDER

Scientists hope to have a smashing time with a particle accelerator four-times the size of the Large Hadron Collider (LHC)

Reported by Lee Cavendish



The LHC has been at the forefront of particle physics since scientists turned it on in 2008. It is the pinnacle of the European Organization for Nuclear Research, more commonly known as CERN, in Switzerland and has made discoveries that even the most sensitive of eyes wouldn't be able to fathom. The Higgs Boson marked a stupendous occasion for physics when they found a fundamental particle within the Standard Model that had previously remained unseen.

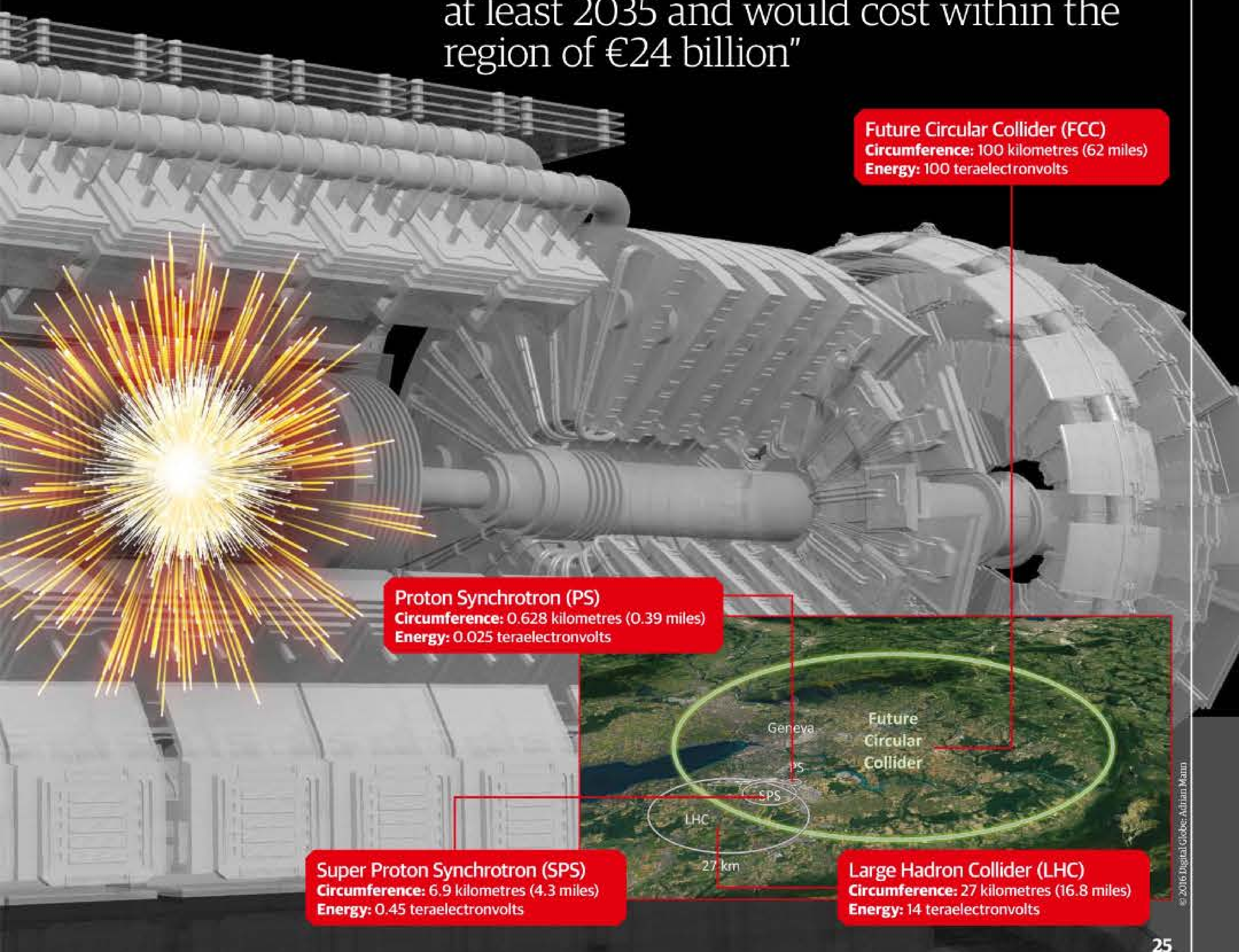
In order to understand how the most massive structures in the universe are governed, such as planets, stars and galaxies, scientists need to understand the smallest particles that comprise them. In the same way that you can only see how much money is in your piggybank by smashing it, scientists apply this same logic to atoms. The only way to see what particles are made of is by smashing them into each other at speeds close to that of light, and scientists and engineers are now planning a bigger and better version of the LHC, named the Future Circular Collider (FCC).

If the LHC is a regular hammer smashing into a piggybank, the FCC will be the equivalent of a sledgehammer. It will be longer and provide much more energy to speed up these atoms. While the LHC holds the current record for largest and most powerful atom collider with a ring of 27-kilometre (16.8-mile) circumference and producing 14 teraelectronvolts, the FCC will flaunt a ring about 100 kilometres (62 miles) in circumference and produce energy of 100 teraelectronvolts.

The LHC has provided a great base for producing a top-quality new hadron collider. In the case of the FCC, engineers have already identified that it must include a state-of-the-art vacuum system, 16 Tesla high-field accelerator magnets, superconducting materials, efficient radio frequency systems and large-scale cryogenic refrigeration. If the project is accepted to go forward the FCC will not be operational until at least 2035 and would cost within the region of €24 billion (over $27 billion).

This post-LHC masterpiece will hopefully answer some of the questions that have eluded scientists for generations, including the mysterious dark matter and anti-matter conundrums. By splitting atoms to an unprecedented level, hypothesised particles may appear that can help explain dark matter and why it makes up almost a quarter of the universe. These experiments may also provide evidence for the abundance of matter over anti-matter, and also delve deeper into the Standard Model by explaining what makes up the Higgs Boson itself. With the help of over 70 institutions around the world, this post-LHC collider could well be the answer to some of the universe's smallest – yet most crucial – mysteries that our current understanding of the Standard Model simply cannot explain.

> "The FCC will not be operational until at least 2035 and would cost within the region of €24 billion"



Future Circular Collider (FCC)
Circumference: 100 kilometres (62 miles)
Energy: 100 teraelectronvolts

Proton Synchrotron (PS)
Circumference: 0.628 kilometres (0.39 miles)
Energy: 0.025 teraelectronvolts

Super Proton Synchrotron (SPS)
Circumference: 6.9 kilometres (4.3 miles)
Energy: 0.45 teraelectronvolts

Large Hadron Collider (LHC)
Circumference: 27 kilometres (16.8 miles)
Energy: 14 teraelectronvolts

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DID A SUPERNOVA SAVE EARTH?

The solid planetary surface we rely on might not have formed if it weren't for one rather energetic radioactive molecule present at the Solar System's birth

Reported by Ian Evenden

Right: The Cigar Galaxy, seen here by Hubble, is five-times more luminous than the Milky Way and is undergoing rapid star formation, with 197 clusters of young stars at the core of that activity

Below: Dr Tim Lichtenberg of Oxford University, whose computer simulations of aluminium-26's effect on the formation of the Solar System answer many questions

The formation of a planet or an entire solar system is never easy. It takes a great deal of violence to hammer a planet into shape as a cloud of gas and dust collapses under its own gravity, forming planetesimals which then crash into each other. Giant impacts can even create satellites around the planets. Cometary and asteroid bombardments add water and pummel craters into the Moon, and only then, billions of years after it all began, do we reach the relative peace of the modern epoch.

Some of the greatest violence in the universe that we know of comes from exploding stars. Supernovae not only mark the end of huge stars that have used up their fusion fuel reserves, but have a secondary effect of seeding the volume around them with useful chemical elements in a process called supernova nucleosynthesis. Dying stars are where we get everything after carbon in the periodic table from, and frequently short-lived radioactive isotopes too.

And sometimes, if the supernova goes off in the right place, it can create a solar system. There's some evidence that this is just what happened in our corner of the Milky Way, with analyses of short-lived radioactive isotopes - or at least the elements those isotopes decay into - found in meteorites showing that the shockwave from an exploding star injected material from that star into the solar nebula that would go on to become our Solar System. At the same time that shockwave pushed parts of the nebula together, causing those regions to collapse and form the system we see today.

> "Not only did a supernova help the process of planetary formation along, but one might have saved the Earth"

And analysis of isotopes in the Solar System tells us something else. Not only did a supernova help the process of planetary formation along, but one might have saved the Earth from becoming a lifeless water or ice world too.

An isotope is a variant of a chemical element, such as carbon or aluminium, which differs in the number of neutrons in its core. All atoms of a particular element have the same number of protons - this is what makes carbon carbon and aluminium aluminium - but the neutron count can vary without it becoming a different element. The most famous example of this is in carbon, where almost 99 per cent of atoms are carbon-12, with six protons and six neutrons. Carbon-12 is stable; it doesn't emit radioactivity, as is carbon-13. Carbon-14, on the other hand - known for its use in carbon dating - has six protons and eight neutrons and undergoes radioactive beta decay, becoming nitrogen-14, which is stable.

Carbon-14 is created in our atmosphere from interactions between cosmic rays and nitrogen, and makes up a tiny trace amount of the Earth's carbon. Its half-life - the time it takes for 50 per cent of a sample of atoms to undergo radioactive decay - is around 5,700 years, and as it's taken in from the atmosphere by plants during photosynthesis, measuring it can accurately date organic material back to around 60,000 years.

But carbon isn't the only element to exhibit this behaviour. Only uranium-235, which makes up just 0.72 per cent of naturally occurring uranium - the rest being uranium-238 - can be used in nuclear reactors, for example. And neither of these elements is the one that turned Earth from a watery dead end to the vibrant world we live on. That was aluminium, and it didn't occur naturally on Earth.

Dr Tim Lichtenberg is a postdoctoral fellow working at the Clarendon Laboratory at the University of Oxford. He studies the formation of planets, and his work, carried out with a team of other academics and theoretical physicists, suggests it was the presence of aluminium-26 - an isotope mainly but not exclusively produced in supernovae - that dried our world out enough to make it habitable. "The presence of aluminium-26 in our Solar System has been known about for quite a while," he says. "It's widely used for dating

© NASA, ESA, and The Hubble Heritage Team; ESO; CSH;

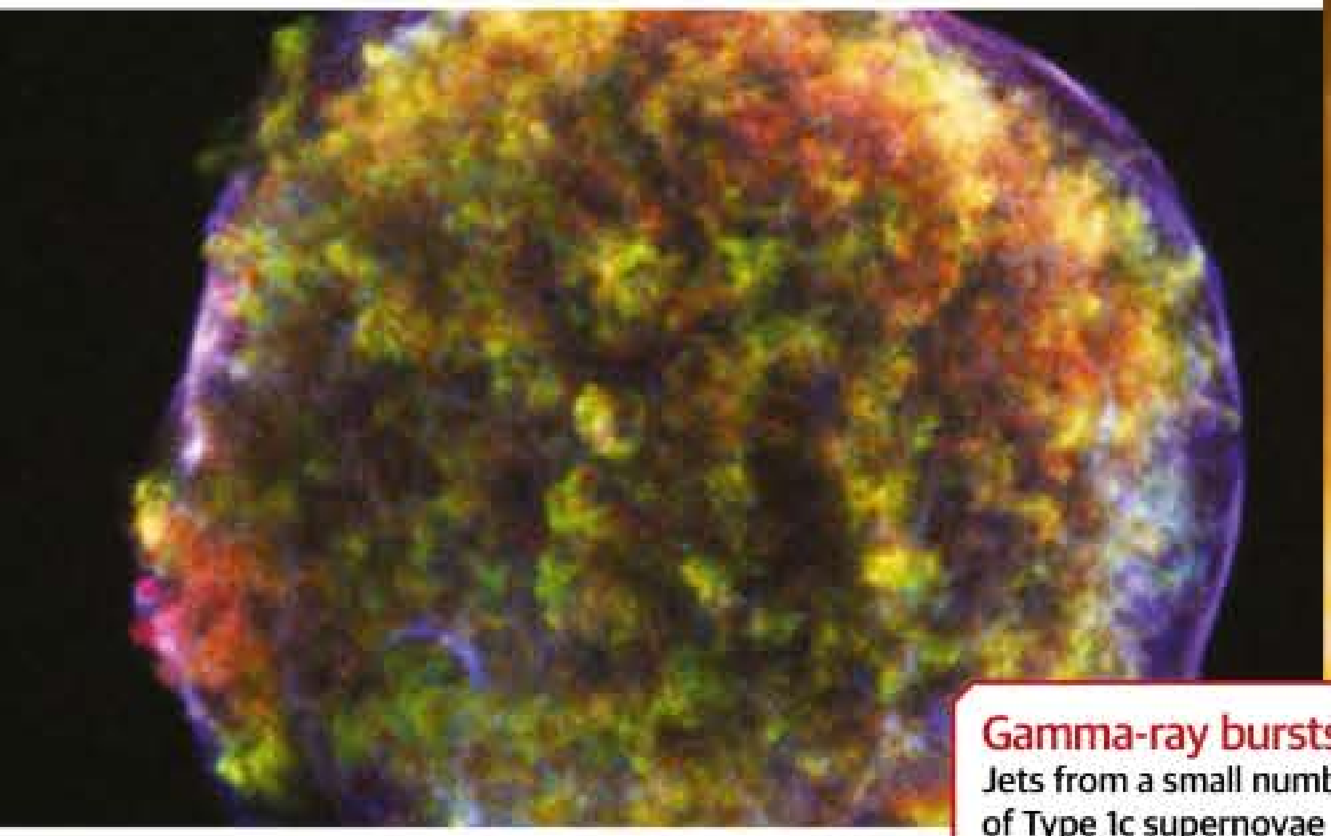
extraterrestrial materials such as meteorites." The isotope has some peculiar properties, however. It gives off a lot of heat as it decays - Lichtenberg describes it as "very powerful" compared with longer-lived isotopes - but with a half-life of only 700,000 years it was only active for a short part of our Solar System's history. Incorporate it into the building blocks of planets, however, and its rapid decay dries them out, removing the water that was added from ice and cometary material.

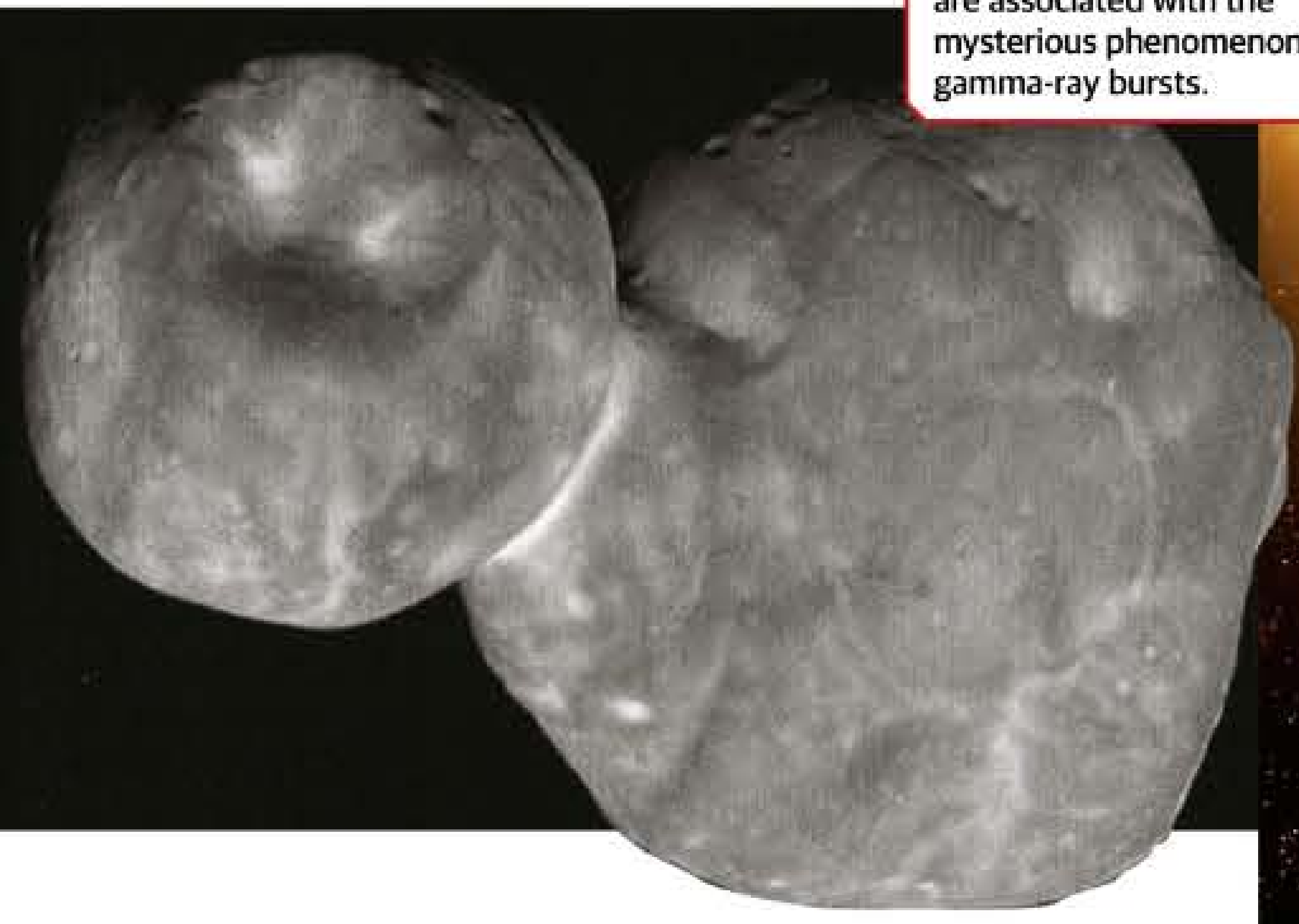
"Because aluminium-26 decays so energetically, all the ice will be degassed from the planetesimals," says Lichtenberg. "So when you start to accrete a planet from these materials, the amount of dehydration that the final planet experiences scales with the amount of aluminium-26 that was present in its building blocks." Earth was less massive back then as it was still in the process of forming. Therefore, water molecules could more easily escape its gravity and be lost to space.

Lichtenberg's theoretical work involves measurements of the composition of rocks out in space, of which there are two main types: those that come from within Jupiter's orbit, which may originate from the interior of Jupiter, and those that orbit outside Jupiter's orbit, which are pristine leftovers from the formation of the Solar System. The presence of aluminium-26, or rather the daughter isotopes it decays into in both points to the isotope being present in every planet as they

Below (top): Type 1b or 1c supernovae are rare, but the more common Type 1a often leaves spectacular remnants, such as this, observed by Tycho Brahe in 1572 in the constellation Cassiopeia

Below: Objects such as Ultima Thule, visited by New Horizons this year, are leftovers from the early Solar System and similar to the planetesimals that combined to form planets





When a star detonates

When a Wolf-Rayet star explodes, its core collapses into either a Type 1b or 1c supernova

Hydrogen
Not present in 1b and 1c supernovae as the strong stellar winds of the progenitor star blow it away. 1c also loses helium.

Silicon
Also missing - the lack of a spectral absorption line for ionised silicon is diagnostic of 1b and 1c supernovae.

Oxygen, calcium, magnesium
Typically, as 1b or 1c supernovae age, these elements become noticeable in their spectra.

Magnetar
The core of the giant star becomes a type of neutron star with an enormously powerful magnetic field. A teaspoon of one would weigh over 100 million tons.

Relativistic jets
Jets of radiation moving at close to the speed of light are emitted from the poles of the magnetic field.

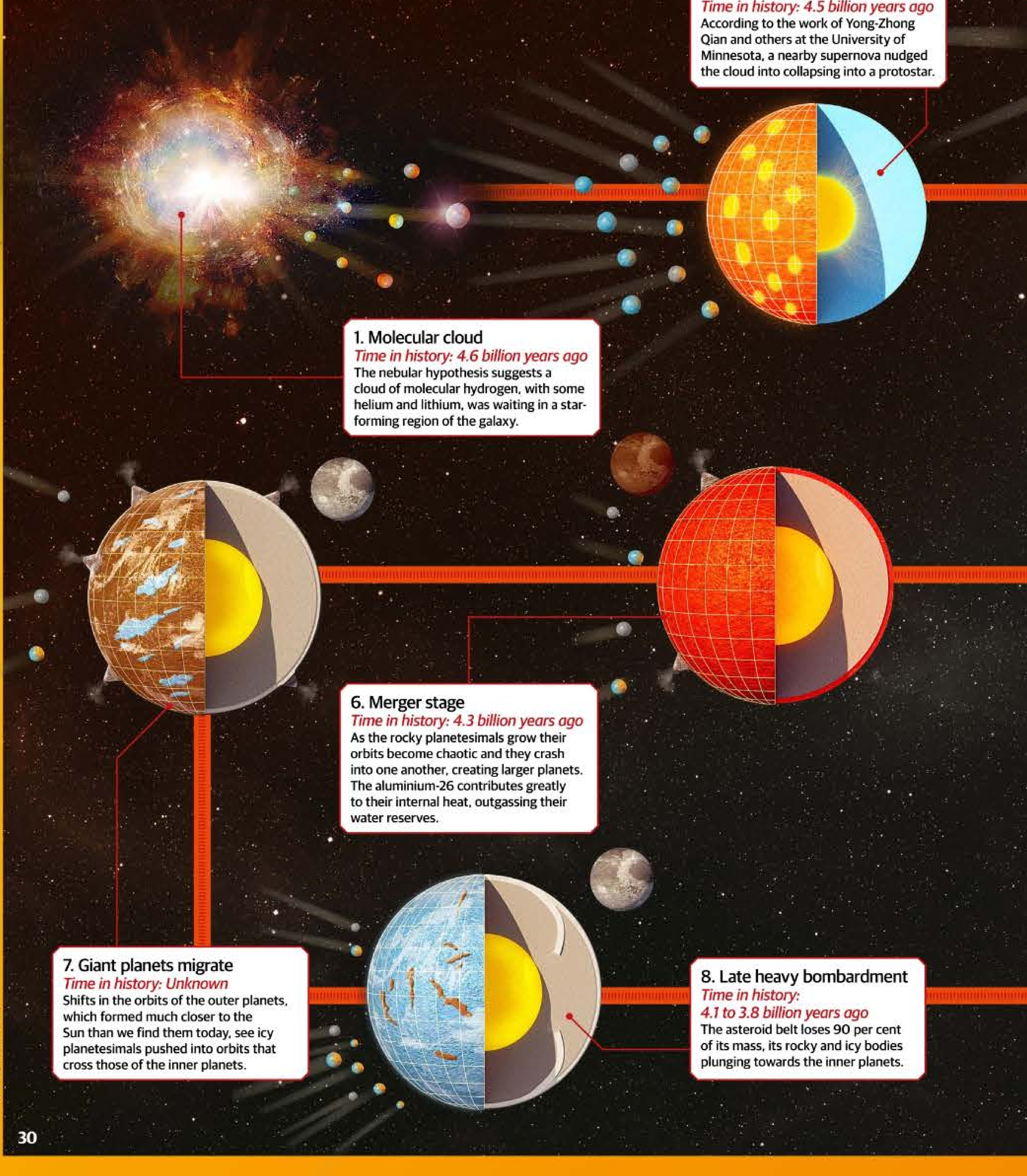
Gamma-ray bursts
Jets from a small number of Type 1c supernovae are associated with the mysterious phenomenon of gamma-ray bursts.

Not as bright
Like their progenitor stars, Type 1b and 1c supernovae are extremely hot, but not as bright as others. They also tend to be redder.

Superluminous supernova
Otherwise known as a hypernova, if a star greater than 30-times the mass of the Sun explodes it can emit more than ten-times the energy of a standard Type 1b supernova.

How Earth was saved from drowning

A push in the right place is all it takes to create a planetary system and dry it out



1. Molecular cloud

Time in history: 4.6 billion years ago

The nebular hypothesis suggests a cloud of molecular hydrogen, with some helium and lithium, was waiting in a star-forming region of the galaxy.

2. Encounter with a supernova

Time in history: 4.5 billion years ago

According to the work of Yong-Zhong Qian and others at the University of Minnesota, a nearby supernova nudged the cloud into collapsing into a protostar.

6. Merger stage

Time in history: 4.3 billion years ago

As the rocky planetesimals grow their orbits become chaotic and they crash into one another, creating larger planets. The aluminium-26 contributes greatly to their internal heat, outgassing their water reserves.

7. Giant planets migrate

Time in history: Unknown

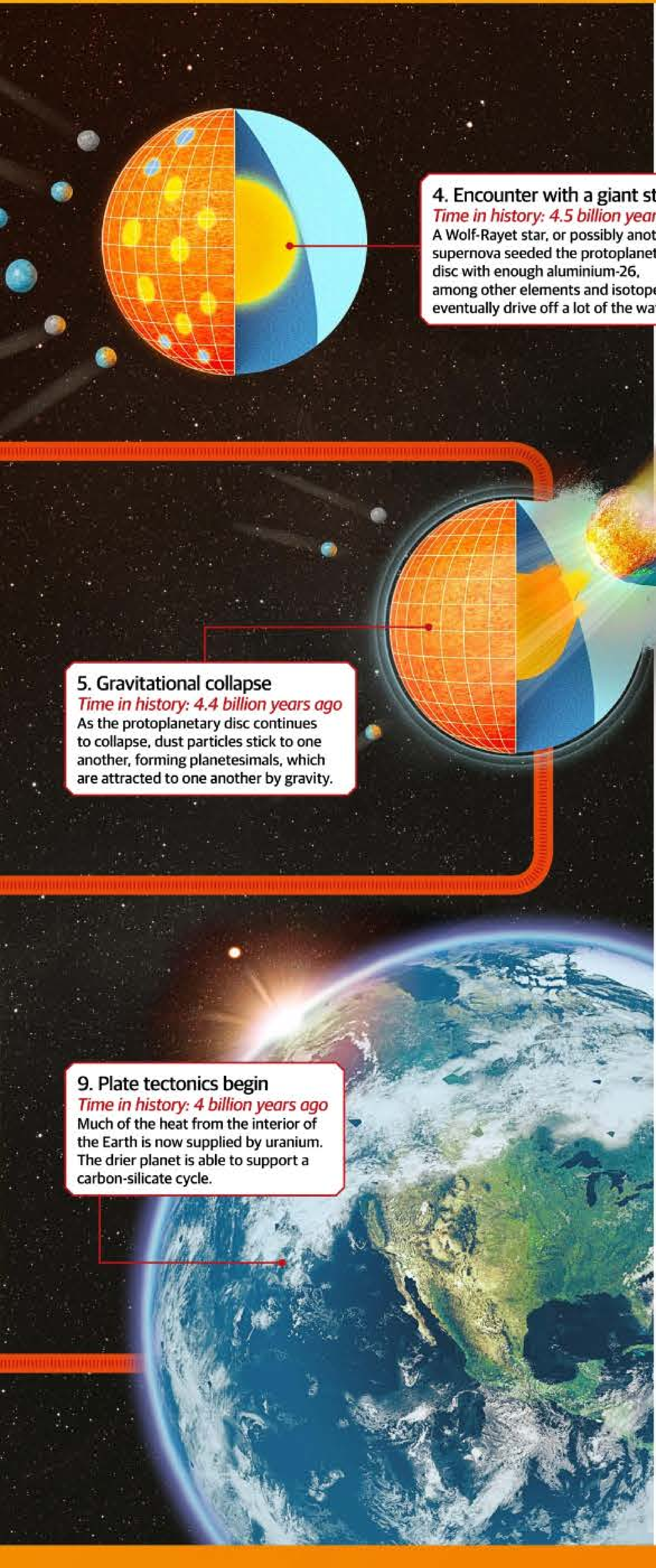
Shifts in the orbits of the outer planets, which formed much closer to the Sun than we find them today, see icy planetesimals pushed into orbits that cross those of the inner planets.

8. Late heavy bombardment

Time in history:
4.1 to 3.8 billion years ago

The asteroid belt loses 90 per cent of its mass, its rocky and icy bodies plunging towards the inner planets.

© NASA, Nicholas Forder



4. Encounter with a giant star

Time in history: 4.5 billion years ago

A Wolf-Rayet star, or possibly another supernova seeded the protoplanetary disc with enough aluminium-26, among other elements and isotopes, to eventually drive off a lot of the water.

5. Gravitational collapse

Time in history: 4.4 billion years ago

As the protoplanetary disc continues to collapse, dust particles stick to one another, forming planetesimals, which are attracted to one another by gravity.

9. Plate tectonics begin

Time in history: 4 billion years ago

Much of the heat from the interior of the Earth is now supplied by uranium. The drier planet is able to support a carbon-silicate cycle.

formed. "Laboratory experiments can detect the daughter isotopes in various meteorite groups, and from this you can infer how much aluminium-26 was present in the early Solar System."

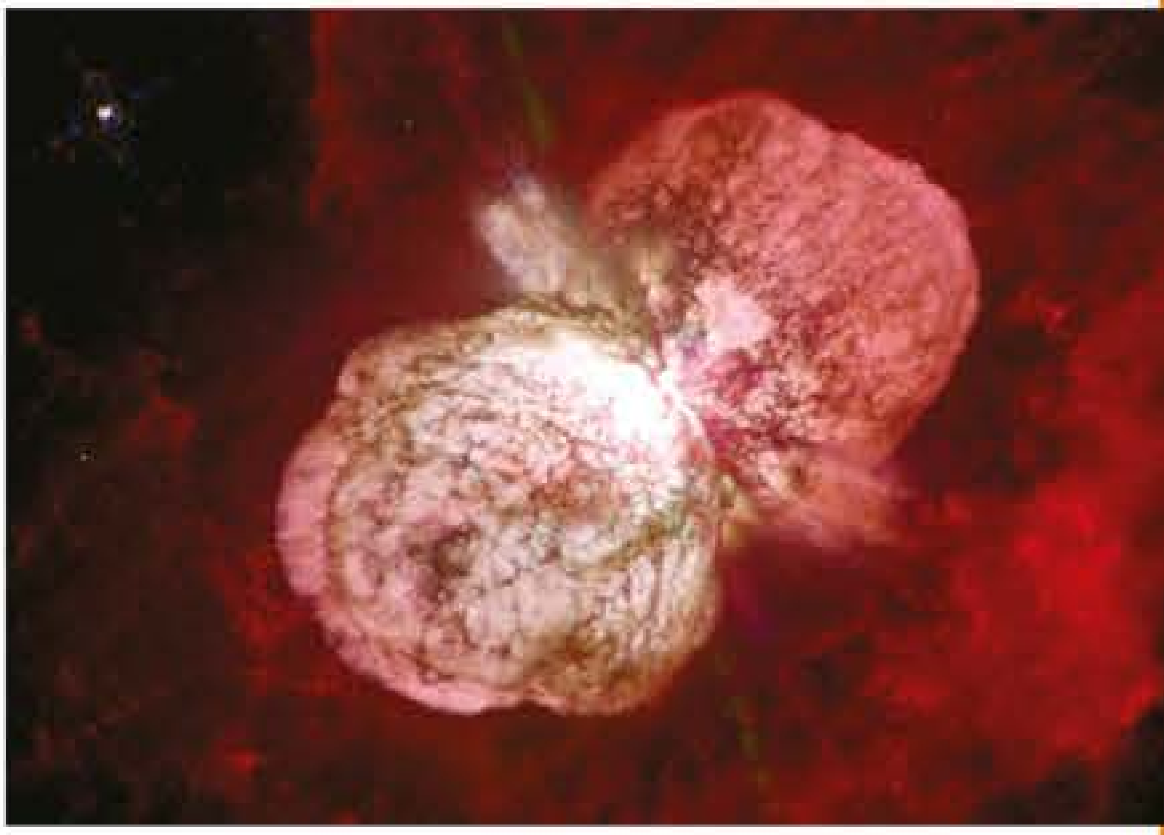
Looking back in time 4.5 billion years isn't an exact process, however, and Lichtenberg's computer models need to be run many, many times before a consensus emerges. He's keen to point out that it's hard to say if the precise amount of water found on Earth is due to aluminium-26, but also that the isotope was an important part of the story. There's something else, too: while aluminium-26 is indeed created in supernovae, he's not going to be tied down on that.

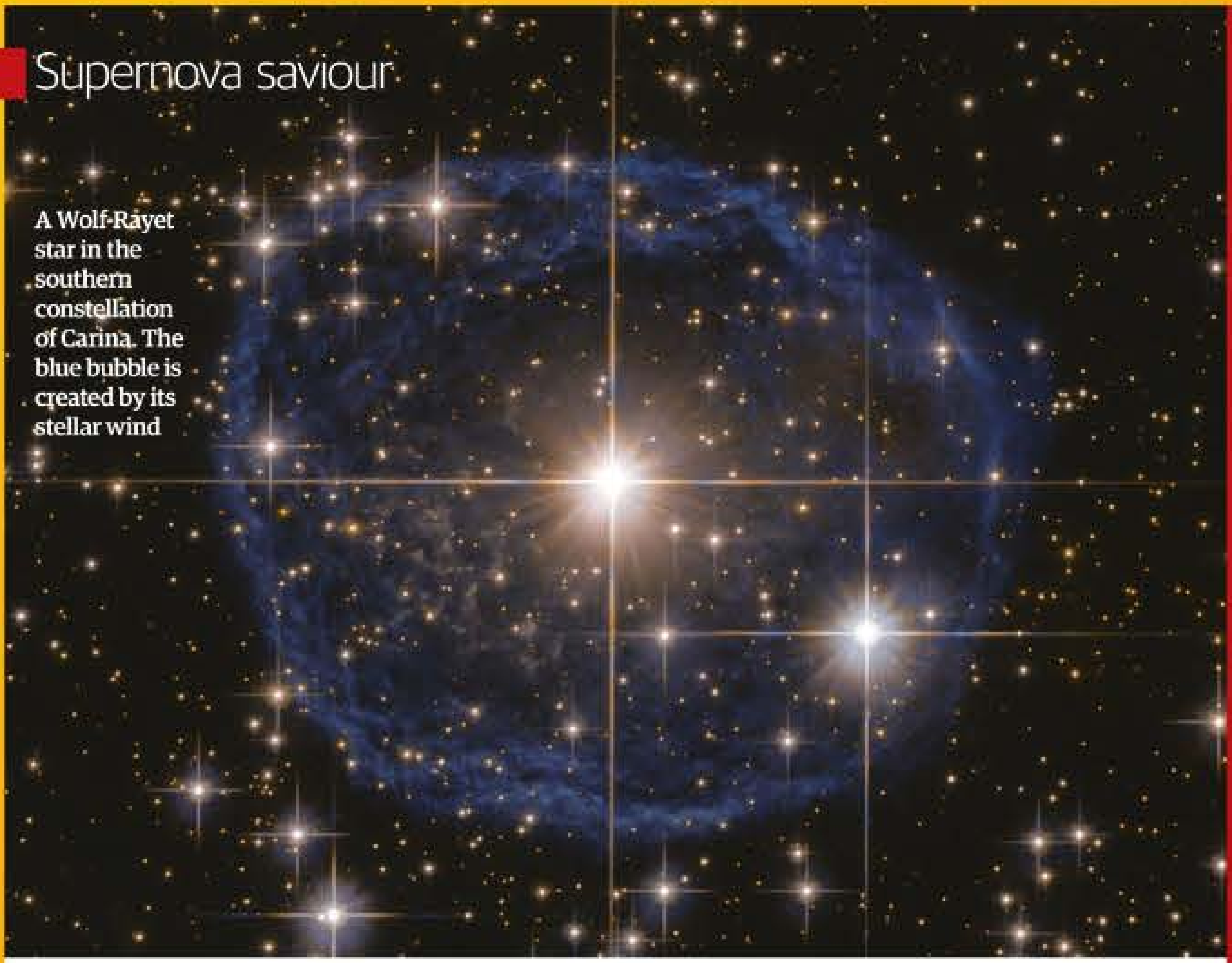
"It came from one or more massive stars in a star-forming region of the galaxy," he says. "What exactly the mechanism was is still debated." When pressed on the nature of this mechanism, Lichtenberg still refuses to utter the word 'supernova'. "It would be more true, and interesting enough to say it came from a supernova progenitor star," he tells us. "Aluminium-26 is expelled from massive stars in a late phase, called the Wolf-Rayet phase. In this phase the star is already partly falling apart - there are massive winds launched from it - so it may be that the Solar System material was around such a star just before it went supernova, or it may have collected the material after the supernova event. But I don't want to take a side."

Lichtenberg's model predicts a drying effect on newly created planets, but given that water is essential for the rise of life as we know it, what would it mean if there was much less aluminium-26 present when a solar system formed? "That would mean the building blocks of the planets would be richer in water," says Lichtenberg. "That doesn't mean that you don't have any dry material at all, but it's harder to accrete a planet that's entirely dry. Most planets that are in planetary systems with little or no aluminium-26 will be extremely water

> "It would be more true, and interesting enough to say it came from a supernova progenitor star" **Tim Lichtenberg**

Below: In the star-forming region of the Carina Nebula is Eta Carinae, a binary star system putting out 5 million-times the energy of the Sun. It's surrounded by the Homunculus Nebula





A Wolf-Rayet star in the southern constellation of Carina. The blue bubble is created by its stellar wind

> "The distribution of aluminium-26 in the early universe and the distribution of habitable exoplanets might be linked"

rich. If you take Earth and change it from one per mille water to one per cent water, then the planet won't have a surface like we know it.

"The icy moons of the outer Solar System would be a better analogue for those types of planets," Lichtenberg continues. "Either you'd have an entire global water layer, or if you had ten per cent water then instead of a global ocean laying on top of a silicate mantle, you would have high-pressure ice phases which would sit at the bottom of the ocean. This is a pretty bad scenario because the geochemical cycles we expect on these types of planet are basically non-existent, so something like the carbon-silicate cycle on Earth [the transformation of rocks from silicate to carbonate and back again by weathering and volcanism] which is very important for buffering the surface temperatures on our planet, couldn't exist on a water/ice ocean world, because there's no interaction between the interior of this planet and the surface."

The high-pressure phases Lichtenberg is referring to are any of the 18 known crystalline structures water can assume under different pressures and temperatures. The cubes you drop in your gin and tonic are known as ice Ih, and have a hexagonal crystal structure. Compress ice Ih at temperatures around -60 degrees Celsius (-72 degrees Fahrenheit) and you get ice II, which has rhombohedral crystals. It's thought the cores of moons such as Ganymede may be ice II. Warm ice II up a little and you get ice III, which has a rectangular crystal structure and is denser than water, so would always sink on a water world. There are many more, some of which don't occur outside the laboratory, and also amorphous ice, which lacks a crystal structure. This ice is the most common form of water in the universe, and if you see noctilucent clouds while waiting for the sky to become dark enough for stargazing in summer, you're looking at a mix of amorphous ice and dust.

We can see from Lichtenberg's work that the distribution of aluminium-26 in the early universe and the distribution of habitable exoplanets might be linked. "All of this is theoretical at the moment, because we just don't have the data, but in principle our Solar System should be one with more aluminum-26. That means that most other systems would have less, and would have these water worlds, but the fraction is very hard to estimate."

That cuts down on the number of habitable planets we could find in the future, so could we one day tell if a system is likely to have had a lot of aluminium-26 in the past? "Today we can't tell if a star came from a dense star-forming region, with many supernova progenitor stars," says Lichtenberg. "If two or three such massive stars were present then you expect more aluminium-26 to be in the planetary systems that form from that star-forming region. The current generation of telescopes is not quite sensitive enough for this, but new space telescopes will be launched in the next years and the number of exoplanets we know about will expand dramatically, and our model predicts we'll find statistical variations."

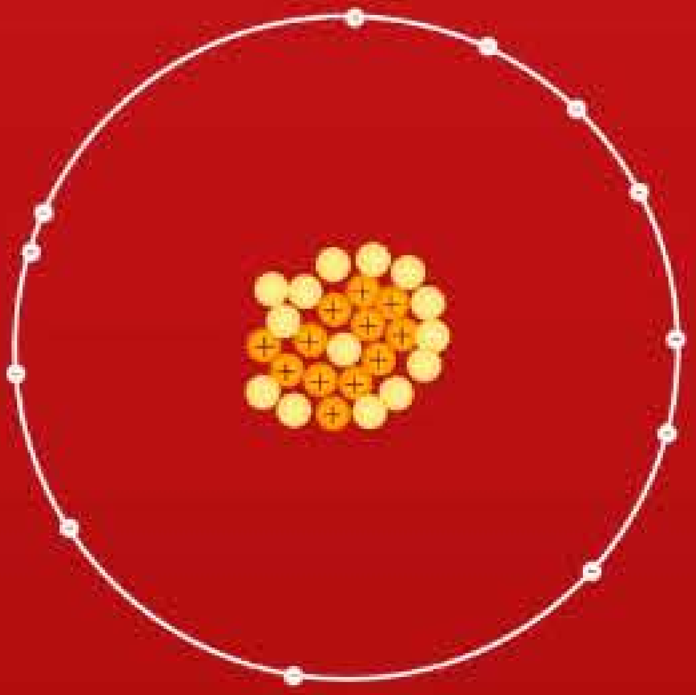
Our largely benign planet owes its existence to the massive temperatures and pressures found in the death throes of the largest stars, and our entire Solar System may only have been created by one of the most energetic events in the universe. In space, the actions of huge objects affect everything down to the smallest dust particle, but tiny atoms of energetic aluminium can have an effect on entire planetary systems, too.

The evidence

The effects a supernova had on our Solar System came falling out of the sky

Magnesium-26

The daughter isotope of aluminium-26 is stable, so won't decay any further. The presence of this isotope shows where aluminium-26 once was.



CK Vulpeculae

Aluminium-26 was detected in this nova remnant, the result of the collision and merger of two dwarf stars, in 2018 by astronomers using the Atacama Large Millimeter/submillimeter Array and the Northern Extended Millimeter Array radio telescopes. It was the first time a radioactive molecule had been definitively detected in interstellar space.

Allende meteorite shower

The largest carbonaceous chondrite ever found on Earth, it burst into fragments over Mexico in 1969 and over two tons of fragments were recovered. Meteorites like this, some of the oldest rocks in the Solar System, are noted for the amount of aluminium-26 they once contained.

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MEET HIPPOCAMP

Neptune's smallest moon has a name - and a violent past

Reported by Mike Wall

IN COOPERATION WITH SPACE.com

A faint and frigid little moon doesn't have to go by 'Neptune XIV' anymore. Astronomers have given the name 'Hippocamp' to the most recently discovered moon of Neptune, which also formerly went by S/2004 N1. They've figured out how big the satellite is as well, and teased out some interesting details about its past, a new study reports.

A team led by Mark Showalter of the SETI (Search for Extraterrestrial Intelligence) Institute in Mountain View, California, announced the existence of S/2004 N1 in 2013. The scientists did so after analysing photos taken by NASA's Hubble Space Telescope between 2004 and 2009.

In the new Hippocamp analysis, which was published in the journal *Nature*, Showalter and his team employed a clever technique they devised a few years back which allowed them to discover the moon in the first place. The scientists 'transformed' eight sequential five-minute Hubble exposures of the Neptune system, rearranging pixels so they could 'stack' images of Hippocamp on top of each other, despite the moon's orbital motion. Essentially, the researchers turned the eight individual exposures into a single 40-minute exposure.

"We came really close to missing it entirely," Showalter said of Hippocamp. "It's too faint to see in a single Hubble [exposure]." This technique is powerful; applying it broadly "might result in the detection of other small moons around giant planets, or even planets that orbit distant stars," astronomer Anne Verbiscer of the University of Virginia, who was not part of Showalter's team, wrote in an accompanying piece in *Nature*.

The new analysis describes a slightly larger world than previously thought: Hippocamp is now believed to have a diameter of about 34 kilometres (21 miles). That's about the same size as Ultima Thule, the weird and distant object that NASA's New Horizons spacecraft flew by on New Year's Day.

Hippocamp circles in the same general neighbourhood as six moons discovered by NASA's Voyager 2 spacecraft during the probe's flyby of Neptune in 1989. Hippocamp is just 12,000 kilometres (7,450 miles) interior to the largest and outermost of these other six, the 420-kilometre (260-mile) wide Proteus.

Like Earth's own Moon, Proteus has been slowly spiralling away from its parent planet for eons - and so has Hippocamp, though at a much slower rate. About 4 billion years ago Proteus was probably right next to Hippocamp and would therefore have gobbled the smaller moon up, Showalter said. As a result he and his colleagues suspect that Hippocamp is younger than Proteus. In fact, they believe the smaller moon was once part of its larger neighbour: Hippocamp likely coalesced from pieces of Proteus that were blasted into space by a comet impact long ago.

Indeed, Hippocamp may trace its origins to the smashup that created Proteus' huge Pharos Crater. Hippocamp's total volume is about 2 per cent of that ejected during the Pharos impact. It's not hard to imagine this small amount of material coalescing to form a moon, Showalter said.

In the 1980s and 1990s astronomers began to posit that the moons of the giant planets endured a number of comet collisions, which caused many of the satellites to break apart. The inferred origin of Hippocamp supports this view of the early Solar System, said Showalter, who has played a key role in the discovery of many natural satellites over the years, including Saturn's 'ravioli moon' Pan in the early 1990s. "This is the first really great example of a moon that got created as a result of an impact," he said.

> "This is the first great example of a moon that got created as a result of an impact"

Showalter and his team also used the transformation-stacking technique to spot the Neptune moon Naiad, which hadn't been seen since its discovery by Voyager 2 in 1989. And the researchers set some limits on the possibility of finding other moons of the ice giant. Their analyses suggest there are no moons wider than 24 kilometres (15 miles) interior to Proteus, and none at least 20-kilometres (12.4-miles) wide beyond that same satellite, Verbiscer noted.

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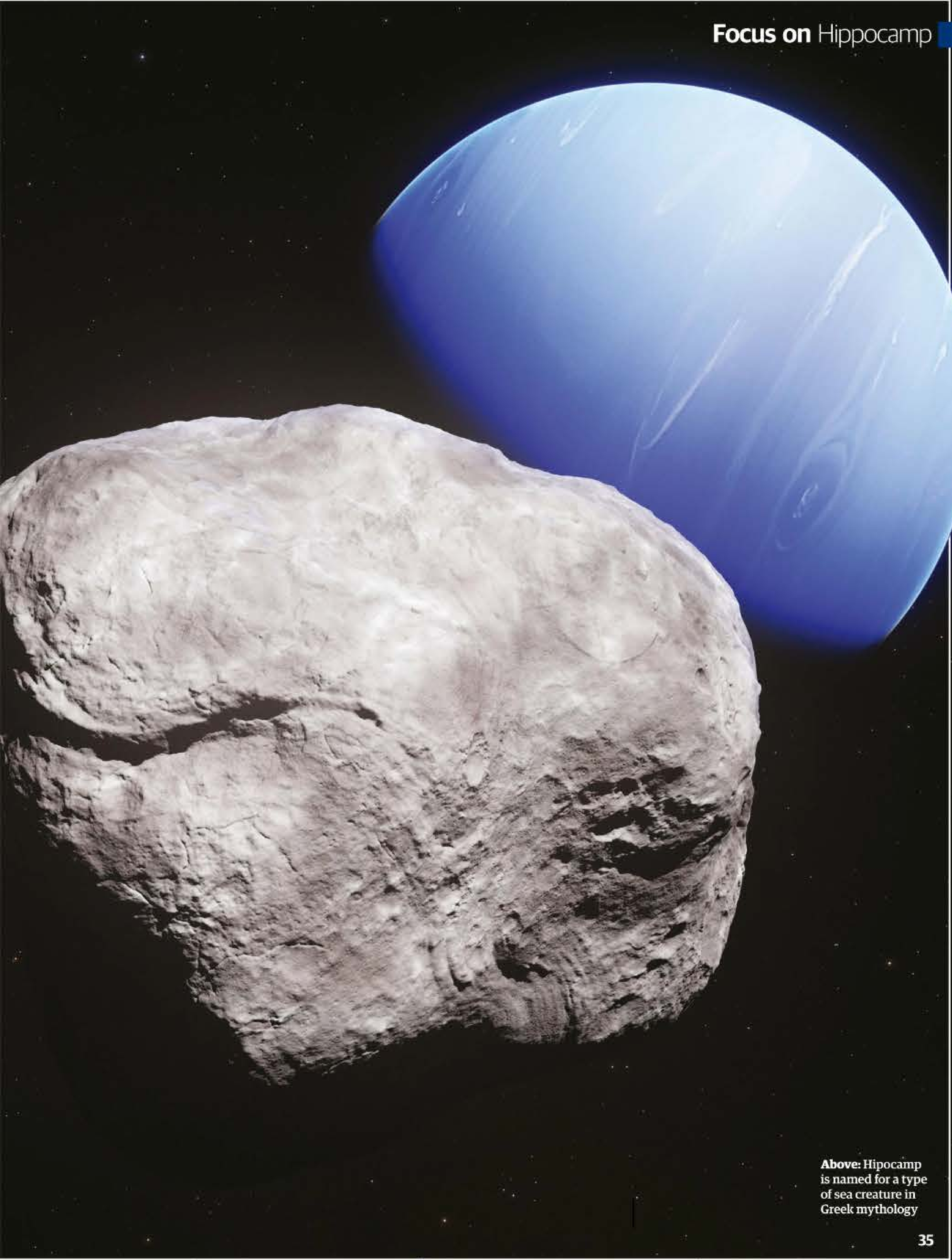


Above: Hipocamp is named for a type of sea creature in Greek mythology

INTERVIEW BIO

James R. Hansen

James R. Hansen is a professor of history at Auburn University in Alabama, United States. He has documented the work of NASA, and his most famous piece of work is the only official biography of Neil Armstrong – *First Man: The Life of Neil A. Armstrong.*

This book, which won the American Astronautical Society's Prize for Astronautical Literature, was the foundation for the 2018 film *First Man*, which stars Ryan Gosling as Neil Armstrong and is directed by Damien Chazelle. Hansen also served as a co-producer of the film.

©Universal Pictures Home Entertainment; Victor John Penner

FIRST MAN THE MAN BEHIND THE MOVIE

The only author to write an official biography on space hero Neil Armstrong, James Hansen reveals his thoughts on blockbuster *First Man* and his friendship with the 'reserved' Apollo 11 astronaut

Interviewed by Lee Cavendish

Left: Neil completed two spaceflights: Apollo 11 and Gemini 8

You were the link between Neil Armstrong's life, his innermost thoughts and the film *First Man*. How do you feel the film turned out? In your mind, did it depict the Apollo 11 story well?
I was anxious about the whole idea of turning the book into a movie from the start. Neil was still alive at the time when the first movie deal was done, but it was my book, he felt, and thus my book to do with what I wanted. I did promise him I would do everything I could in my power to try and make the movie as authentic as possible. So I had this pretty awesome sense of responsibility which I did my very best to materialise and use to influence the film, and I think I did.

I reviewed every one of the scripts and everything from the preliminary outline to the very end. I was on set for most of the movie. It was exciting; it was the first time I've been involved in movie production, but it was also quite stressful because there were times when I thought things weren't quite what they needed to be in terms of the dialogue they would have Neil saying. Overall I think the filmmakers did a brilliant job. They ended up having the same - or some that were very close to the same - sense of responsibility to the facts that I did.

But a movie is a movie, and a non-fiction book is a non-fiction book. There are major differences, so there were things about the movie that I simply had to accept. I suppose because even though I was a co-producer on the film, I only had my power of persuasion. I was persuasive in many instances, but in some cases my persuasive power was not enough to move them off what they wanted to do. But I love the film... I think it's a fabulous film.

Were there disputes with the producers when it came to balancing Apollo 11's reality and science with the creativity of filmmaking?
There was some, indeed. In fact, I was told by one of the producers on one occasion, he said to me: "You know Jim, some authors are kicked off some sets." I guess they were sending me a message. I wasn't trying to be intrusive and I tried to be a team player, and I was.

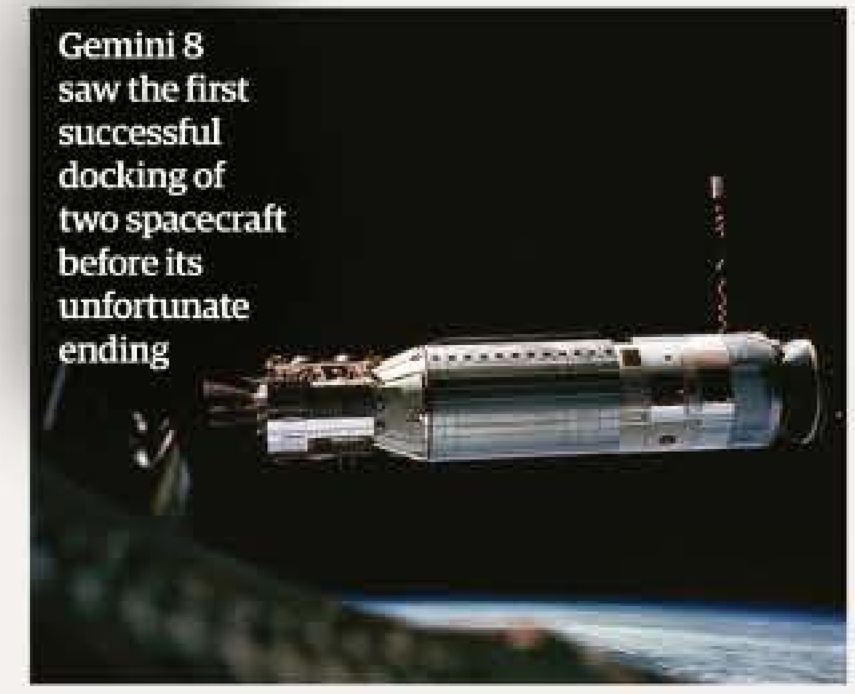
I got to know the director [Damien Chazelle] and the chief actor, Ryan Gosling, playing Neil, quite well and they both said to me: "Jim, if you have any comments to make, just come directly to us."

Well that was nice of them to say that, but that's not what the producers of the film - that I was working with more closely - or the screenwriter wanted me to do. They just always wanted me to go straight to them.

Did helping create *First Man* bring back any of your own personal memories of watching the first Moon landing in 1969?
Yes it did. I was 17 years old that summer [the Moon landing happened], and I wasn't like a model [rocket] builder, and I wasn't particularly following the space programme day by day. But I was very

Above:
The Apollo 11 mission was excellently portrayed in the 2018 hit film

Below:
Claire Foy found James' work with the film very beneficial



Gemini 8 saw the first successful docking of two spacecraft before its unfortunate ending

attentive as a teenager as to what was going on in the news. I remember watching many of the space missions carefully and certainly watched the complete landing and moonwalk of Apollo 11, so it did bring back a lot of memories of that.

It also brought back some more recent memories with Neil. I had gone through the landing with him, and the EVA [extravehicular activity], in the book. I had gone minute by minute through it all; I mean I had him take me through the entire thing. Then there had been some new film that the Lunar Reconnaissance Orbiter (LRO) had taken of all of the [Apollo] landing sites. I remember a presentation he [Neil] made where you saw the film from the original Apollo 11 Eagle with the camera looking outside the window coming down to a landing, this was next to the new, high-definition recording that the LRO had made and Neil recalled - inch by inch, foot by foot - the landing, and I had listened to that very carefully.

Did you ever have any of the actors come directly to you for advice?

Yes I did. At least the two main characters, Ryan Gosling playing Neil and Claire Foy playing Janet, they both came to me. Ryan I think more often than Claire. However I did have a long conversation with Claire one evening where she asked me questions about Janet and the marriage, and I gave Claire all of the tape-recorded interviews that I had done with Janet Armstrong back in 2003 for the book - which was about 16 hours of tape.

Claire listened to almost all of them, not only to pick up on the mid-western/Chicago dialect that Janet had, but also to get insights into Janet as a character. In some of her interviews I've heard Claire specifically mention how important those interview tapes were for her. So yes, they did come to me, and a few of the other actors did as well, but mostly Ryan wanting to know more about Neil.

What sort of character was Neil Armstrong in real life?

In some ways he was a very simple and very straight-forward type of person, but at the same time very complex. That sounds like a contradiction, but the human personality is an amazing and difficult thing.

Neil could be very closed off emotionally in many respects, and very private and unwilling to share his inner thoughts. But at the same time - in certain social settings when he was comfortable, certainly around his fellow pilots and astronauts - he could be very friendly, had a great sense of humour and was just a great person to be around.

I was interested in getting under his skin in a way. In writing the book, I didn't really want to turn it into a psychobiography where I try to apply psychology concepts to his personality. At the same time, I did want to understand what made him tick.

In the book, what I could do and did at length is look very carefully at his childhood. I'm a strong believer as a biographer and a human being that the child is the father to the man. You have to really understand what goes on in childhood development, for example his parents, siblings, family and community, to really understand why a person becomes what he or she becomes. You can take the time in a long biography to do that kind of analysis, whereas in a movie... I mean, our movie picks up in 1961 when Neil is 31 years old, and there are really no previous stories or facts to suggest how he became the way he was. So you essentially pick him up mid-stream, and I think that's an unfortunate necessity that that's how a movie like this has to be made because you're missing out on a lot of background to explain who he is.

You said he could be closed off. How did you develop a relationship so that he could open up to you for the biography?

Well, it's interesting. I recently looked back at my contract with him, which was a simple contract I drew up based on an old book contract I had, but Neil had originally agreed to give me about 18 hours of tape-recorded interviews. We ended up with 55 hours of tape-recorded interviews, so he didn't limit me to what the contract said. We developed a chemistry and went about it in a sensible way.

The 55 hours I had with him were over several months, and that's what was so special and extraordinary for me. People who have had interviews with Neil, to which he granted only a small number of interviews over the course of his life, but the ones he did grant, you'd be lucky to have 15 or 20 minutes with him. I had 55 hours with him. I could take my time; I didn't have to rush into questions about the Moon landing.

I went very systematically through his lifetime and I gave him the questions in advance in writing so he could see what I was going to ask him. Of course I deviated off the cuff - a lot of things came up spontaneously. But over time a friendship of sorts developed, to the point where he was almost unaware that the tape recorder was rolling. I was able to ask him more and more questions that got deeper and deeper into his personal story.

Was there any standout moment or event that had the biggest influence on his career?

Well, I really think that his years as a naval aviator were really, very formative. He had gone to Purdue University on a naval scholarship and when the Korean War broke out he was only two years into his schoolings, so he had to stop school and train as a naval aviator and then go fly in 78 combat missions in Korea. He was only 20 years old; he was the youngest member of his fighter squadron in what happened to be one of the first all-jet airplane fighter squadrons in the US Navy.

© NASA; Universal Pictures Home Entertainment;

I got to meet most of his squadron mates that were still alive, his Fighter Squadron 51, and Neil was very close to those men. Over the subsequent years he always made every reunion of that fighter squadron, whereas astronaut reunions he was quite reluctant to attend a lot of them and only attended some of them.

So it was really the years as a naval aviator that had a big influence on him. He was a combat naval aviator for only two years, and he lost enough for losses in his life [in terms of members in his squadron].

The movie creates this in terms of his daughter and some of the astronauts, but he lost a couple of very close buddies that flew with him in Korea as a young man. So it goes beyond what is shown in the film. The film doesn't cover anything related to the Navy. I felt from talking to Neil, and talking to the men that flew with him in combat, that experience was so formative and seminal in his whole outlook on life and on flying.

NASA's Gemini 8 was a spaceflight mission commanded by Neil which experienced the first critical in-space system failure for NASA – a potentially fatal event. What was Neil's reaction to that and his thoughts afterwards?

His main reaction was disappointment and concern that maybe there was something else he could have done differently which could have saved and extended the flight so they could have completed the entire mission instead of having to come straight down. Ultimately he realised he couldn't have, as did his bosses at NASA, after the investigation. Given the systems he was working with and what had happened, he did everything they needed to do to get out of the spin and get home safely.

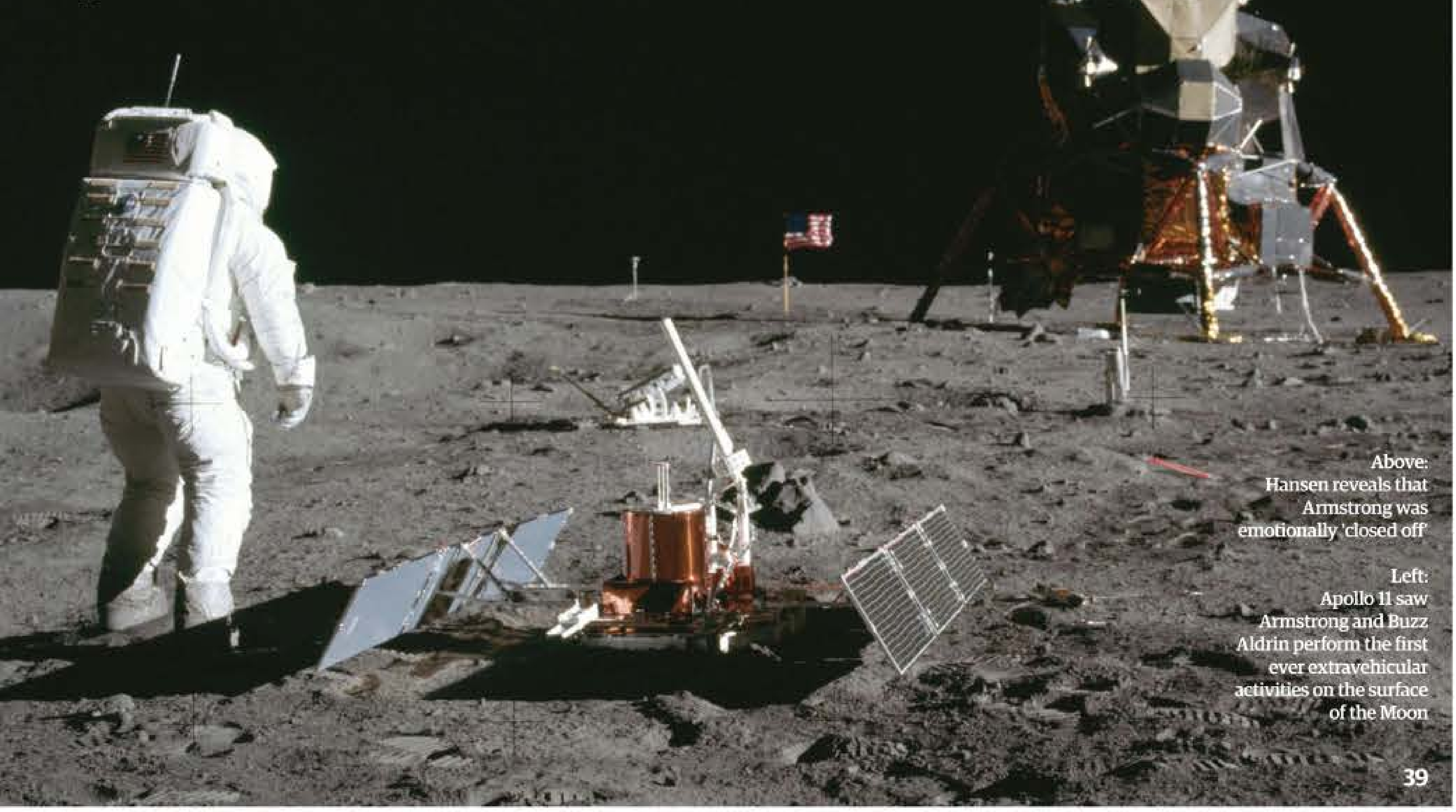
Neil was something of a perfectionist, and always questioned his own actions. I think he may even have entered into a period of depression following Gemini 8. I mean he was certainly glad he and Dave [Scott] were still alive, but there was Monday morning quarterbacking by some of the other astronauts that suggested behind Neil's back that he could have done it different, or even that they could have done it differently and it could have worked out better. But Neil and NASA came to realise that there wasn't really much else they could have done.

Was it a case of coming back stronger and more determined for the Apollo missions?

Yes, I think probably so. He was able to put things like that behind him and move on to the next task. He was an engineer first and foremost, and so everything about a spacecraft and its operational systems, everything about how it flew, everything about the simulators that they were training in, they all fascinated him. He would have studied them to a degree that was more so than any of the other astronauts. He was very dedicated to learning about what it all was. Doing Apollo was going to be a big, big challenge and, after Gemini 8, to have the Apollo program moving ahead with this fire put everything else on hold. I think there was plenty for him to refocus on, and he didn't have to dwell on what went wrong with Gemini 8. Once that was put to bed and no fault was found in anything he and Dave had done, Neil accepted that and moved on to what the next challenge was.

***First Man* is now available on 4K Ultra HD, Blu-ray and DVD from Universal Pictures Home Entertainment**

"Neil could be very friendly, had a great sense of humour and was just a great person to be around"



Above: Hansen reveals that Armstrong was emotionally 'closed off'

Left: Apollo 11 saw Armstrong and Buzz Aldrin perform the first ever extravehicular activities on the surface of the Moon

THE WEIRD AND WONDERFUL

WHAT'S THE STRANGEST THING SENT INTO SPACE?

From LEGO to pizza, this list of space oddities will have you thinking: 'How have they managed to end up there?'

Written by Lee Cavendish

Space exploration is relentless. There's a constant stream of satellites, astronauts and spacecraft waiting to be jettisoned beyond the confines of Earth. Since exploration began in the 1960s some intriguing and amusing items have somehow found their way up there. Whether they had a legitimate reason or were done just for some good-natured fun, there have been some strange items sent into space.

All About Space takes a look back through the years and brings to memory some of the more unusual cosmic visitors – with the evolution of commercial spaceflight, who knows what weird things will be sent there next!

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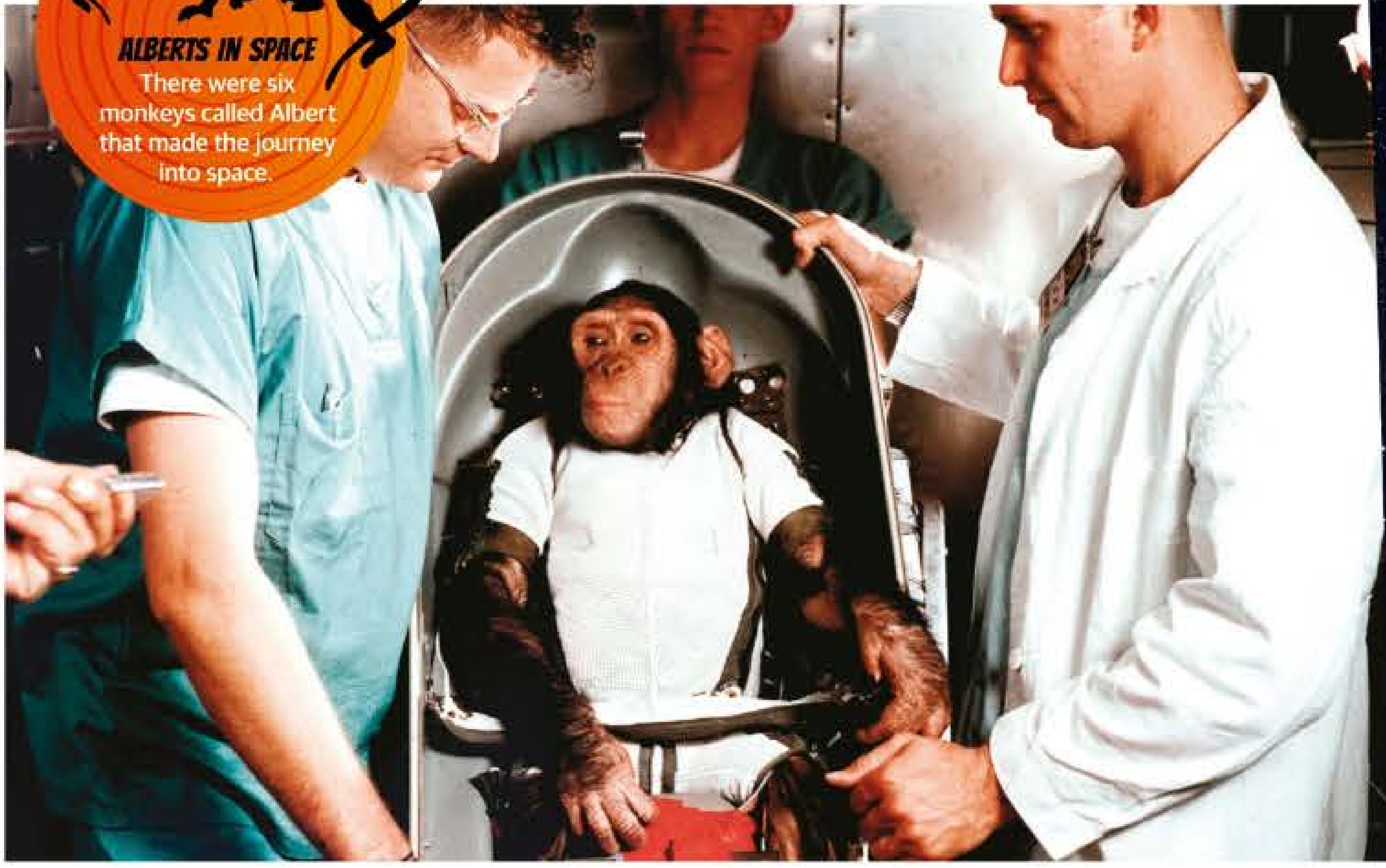
ALBERTS IN SPACE
There were six monkeys called Albert that made the journey into space.



OTHER CREATURES OF EARTH

Sadly, during the early stages of space exploration in the 1940s through to the 1960s, animals were used for the testing of space flights. In recent times no such animals have been harmed in the development of space exploration, but these wonderful animals helped us get to where we are now.

Different animals have been sent into space in order to understand the impact of microgravity on the body, but there are a few names that stick out among the crowd. The first that springs to mind is Laika, the Soviet dog, whisked from the streets of Moscow, Russia, to become the first animal to orbit Earth with the launch of Sputnik 2 in 1957. Unfortunately Laika did not survive the space flight.

Ham is another popular character as the first chimpanzee to be launched into space by the United States in 1961, three months before Alan Shepard's flight, and was also trained to perform tasks during the spaceflight. His flight was only 16 minutes and 39 seconds long, with his vital signs monitored while performing simple tasks, before he returned back to Earth, suffering only a bruised nose. There are many other animals that paved the way for human exploration, and it is vital not to forget their efforts.

Above: Ham was trained to pull on levers during spaceflight in response to flashing lights

Below: Schirra (seated) and Stafford snuck their instruments onto Gemini 6

VOYAGER'S GOLDEN RECORDS

In the 1970s famous American astronomer and science communicator Carl Sagan carried a lot of weight in the construction and implementation of deep-space exploration missions. Sagan also held the view that if these spacecraft were to be picked up along the way by an extraterrestrial intelligent life-form, how would they know it was from Earth?

This line of questioning is what led to the famous Voyager Golden Records. NASA's Voyager 1 and 2 were launched in 1977, only 16 days apart, and they sent back remarkable pictures of our Solar System and showed us things we'd never seen before. But aliens may have the same reaction if they come across one of the Voyager spacecraft, so Carl Sagan and his committee created a golden record in an aluminium jacket with instructions on how to play it.

If it was to be played the record would include 115 images in analogue form, greetings spoken in 55 languages followed by the 'sounds of Earth' and a 90-minute selection of music throughout the ages from around the world.

MUSICAL INSTRUMENTS

When humans made the journey into space, it wasn't long before music followed. The first instance was a Christmas-themed prank aboard NASA's Gemini 6 when command pilot Wally Schirra and pilot Thomas Stafford made the first manned rendezvous with Gemini 7.

On 16 December 1965, Schirra went on his radio to report: "We have an object, looks like a satellite going from north to south, probably in polar orbit. Looks like he might be going to re-enter soon. You just might let me pick up that thing. I see a command module and eight smaller modules in front. The pilot of the command module is wearing a red suit."

Only afterwards did he break out into the *Jingle Bells* music using his tiny, four-hole, eight-note Little Lady model harmonica, with Stafford playing five small bells. This was a prearranged prank between Schirra and Stafford, and also the first record of musical instruments played in space. The instruments are now on display at the Smithsonian National Air and Space Museum in Washington DC, United States.

SPACE BURIALS

Space is teeming with dangers that could potentially kill anyone who ventures there. But who would have thought that once someone dies they'd want to be sent there? That has been the case with a few people over the years in the form of their ashes.

This may seem peculiar, but it has been the last wish of certain people who have had a strong affinity with the night sky and space. The first occurred in 1992 with Gene Roddenberry. His will requested that his remains boldly go where no one has gone before, and a portion of his ashes were launched and returned to Earth on the Space Shuttle Columbia for the STS-52 mission.

Another famous example is Clyde Tombaugh, the American astronomer who discovered Pluto in 1930. NASA's New Horizons mission was shot at insanely high speeds towards the distant dwarf planet and former ninth planet of the Solar System, but on board the spacecraft were the ashes of Tombaugh. Tombaugh passed away nine years before the launch of New Horizons in 2006, but a portion of his ashes were placed on the spacecraft as per the request of his will, just like with Gene Roddenberry.

Left: New Horizons, and Clyde Tombaugh, left Earth on 19 January 2006

PIZZA DELIVERY

It's Friday night, cooking is not on the agenda and a pizza delivery seems the most tempting order. So you ring up Pizza Hut, order your favourite pizza and wait half an hour for the eagerly anticipated knock at the door. In 2001 a similar routine was conducted in the depths of space as Pizza Hut became the first company to make a delivery into space.

Through an odd turn of events Pizza Hut struck a deal with Russian space agency Roscosmos - reportedly worth £700,000 ($1 million) - to have a pizza delivered to the International Space Station. Russian cosmonaut Yuri Usachov was the lucky recipient and enjoyed some Earth comforts as he posed for the cameras with a big thumbs up.

This pizza was tweaked slightly to undergo this unusual delivery. Salami was used instead of pepperoni, as pepperoni did not withstand the 60-day testing process, and extra salt and spices were used in order to tingle the taste buds that are depleted in microgravity. You may be wondering what the scientific or engineering benefits of delivering a pizza over 400 kilometres (250 miles) on a rocket to the ISS are... The answer, virtually nothing. But at least Usachov had a good meal!

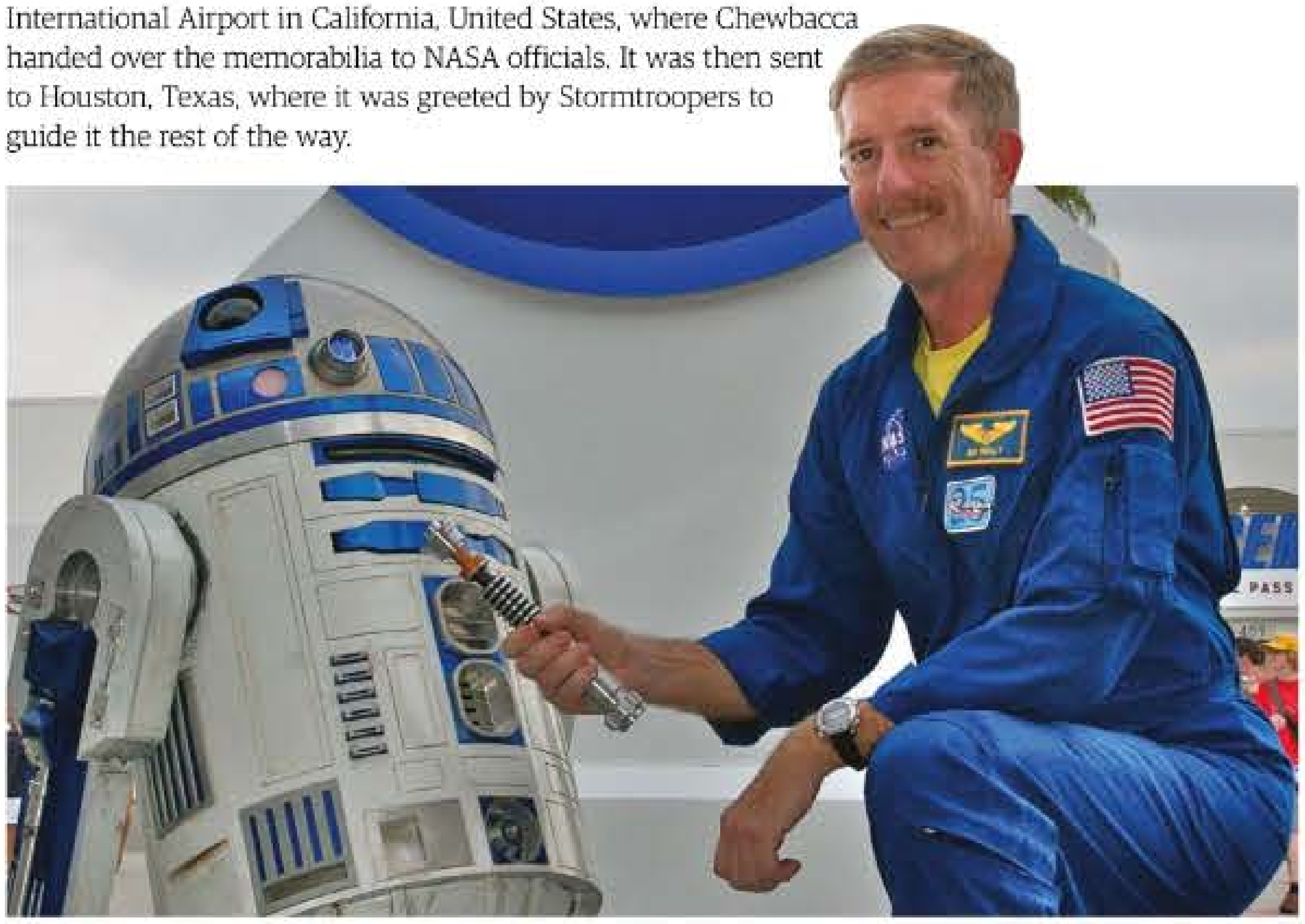
Above: Pizzas are not convenient for space flight - but they are delicious!

LUKE SKYWALKER'S LIGHTSABER

Star Wars has inspired generations of sci-fi fandom, still present and popular today. This series of space adventures, where the heroes travel at light speed and visit endless worlds, has inspired many into the world of astronomy and space exploration.

In 2007, as the International Space Station was being built by a series of Space Shuttle missions, Mark Hamill's - who played Luke Skywalker - lightsaber that he used in the 1983 film *Episode VI: Return of the Jedi* was flown into space and back. This was to celebrate the 30th anniversary of George Lucas' incredible franchise while a team of seven astronauts were jettisoned into space to deliver and assemble the Harmony module, also known as Node 2.

Prior to the launch an official ceremony was conducted at Oakland International Airport in California, United States, where Chewbacca handed over the memorabilia to NASA officials. It was then sent to Houston, Texas, where it was greeted by Stormtroopers to guide it the rest of the way.



Right: R2D2 and NASA astronaut Jim F. Reilly posed with the lightsaber prior to the 14-day STS-120 mission

THE FIRST INTERSTELLAR ADVERTISEMENT

Doritos beamed the first interstellar advertisement in 2008 to a system 42 light years away in the constellation of Ursa Major.

© NASA; SpaceX; JHUAP; LEGO; Heritage Images / Getty; Martin Lee / Alamy Stock Photo

LEGO FIGURINES

Sending LEGO into space was not so much a public relations stunt as it was an effort to get children interested in space exploration, in particular the spacecraft that was going to help humanity understand the largest planet in the Solar System, Jupiter.

NASA's Juno spacecraft was launched on 5 August 2011, and along with a well-tuned instrumental suite capable of probing the enormous gas giant there were also three LEGO mini-figurines that included the Roman god Jupiter, the spacecraft's namesake, Jupiter's wife, Juno, and Galileo Galilei, who made several important discoveries about Jupiter. This trio was placed on the Juno spacecraft as part of the Bricks in Space project, an outreach programme between LEGO and NASA to inspire children into STEM-related subjects.

"NASA has a long-standing partnership with the LEGO company," said Scott Bolton, principal investigator for the Juno mission and space science and engineering director at the Southwestern Research Institute in San Antonio, Texas, United States. "Any of you that have children know that LEGOs are very popular with kids, as well as really helping to teach them about building and engineering."

TO INFINITY AND BEYOND!

Buzz Lightyear, the iconic character from Pixar's *Toy Story*, made a trip into space aboard the Discovery mission STS-124 in 2008.

STARMAN HEADING FOR THE STARS, MAN

More recently SpaceX performed an extravagant launch of the Tesla Roadster and Starman - SpaceX's spacesuit-clad mannequin driver. Both Tesla and SpaceX are owned by Elon Musk, and he and his team thought that this car delivery would be an appropriate way to commemorate the maiden launch of the Falcon Heavy rocket in February 2018.

The test flight had its ups and downs in that the outer cores successfully landed, but the rocket's central core missed its drone ship. However, it was the launch of Starman and the shining cherry-red Tesla that caught the public's attention. SpaceX even had a live stream from within the car that had the words 'don't panic' on a screen next to the steering wheel while blaring out David Bowie's 1969 hit song *Space Oddity*. And in space it will remain - it is in an orbit around the Sun which crosses the orbit of Mars and will return back within the orbit of Earth - at least for the foreseeable future.

Right: SpaceX's Falcon Heavy will launch more than Tesla cars when fully operational

SNEAKY SANDWICH

Astronaut John Young snuck a corned beef sandwich aboard the Gemini 3 mission.

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MYSTERIES OF THE UNIVERSE

THE BLACK KNIGHT SATELLITE

For decades different discoveries have been linked to a single possible spacecraft of extraterrestrial origin. But what is it?

Reported by David Crookes

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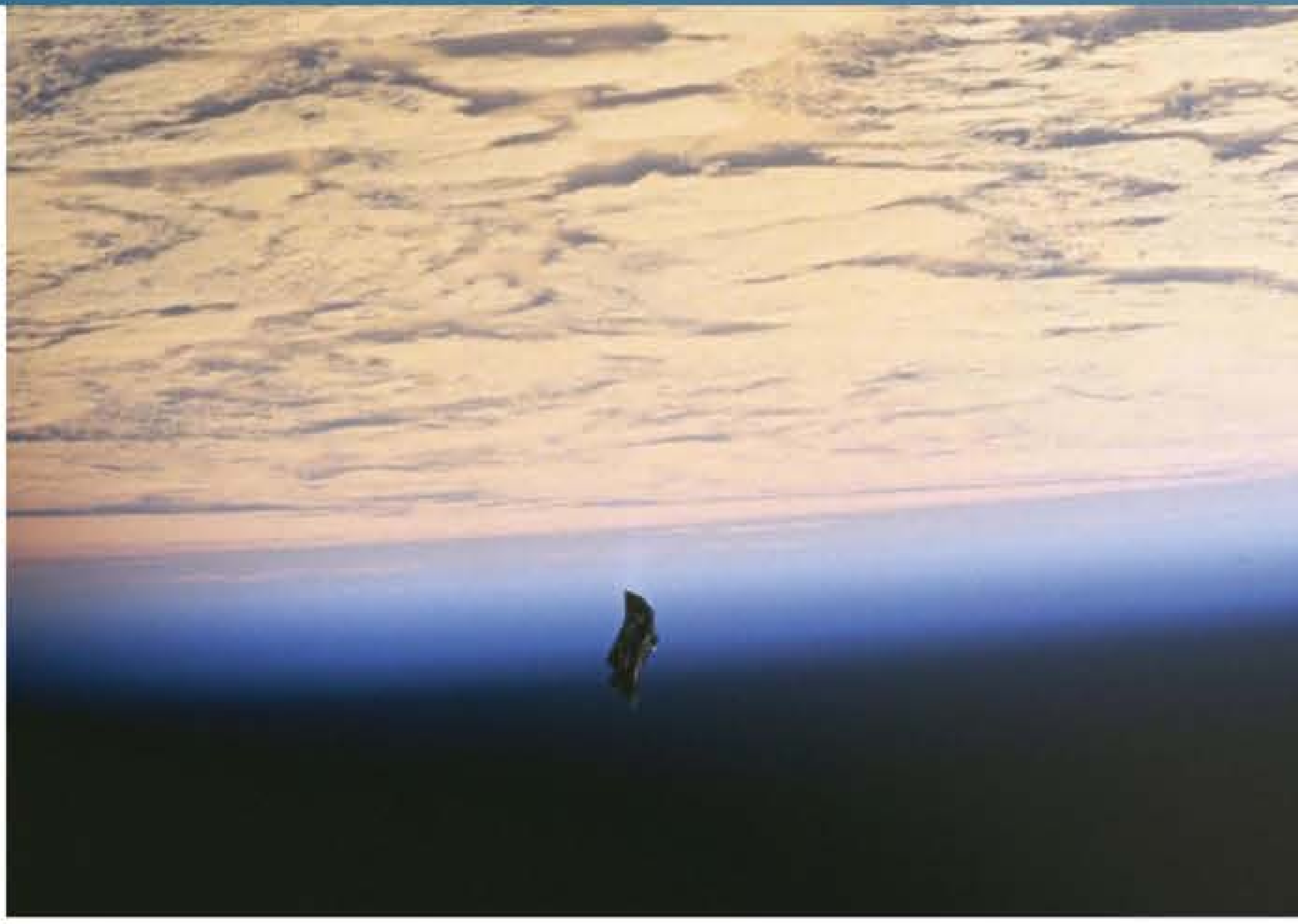

Sometimes the introduction of a news report will stop you in your tracks, forcing you to reread in fear you didn't quite grasp its point the first time. That was certainly the case when *Mail Online* published a story on 21 March 2017: "An alien satellite set up more than 12,000 years ago to spy on humans has been shot down by elite soldiers from the illuminati, UFO hunters claim." And with that the conspiracy surrounding the so-called Black Knight satellite appeared to be very much alive.

This year marks the 120th anniversary of the moment conspiracists believe the existence of the Black Knight was recorded. Those who subscribe to the theory lay claim of an extraterrestrial spacecraft in near-polar orbit of the Earth, although they draw upon evidence so disparate that it's not entirely clear why people link them. What they amount to, however, is an intriguing set of ingredients that, taken together, cause people to scream loud about potential cover-ups by NASA and the government. In that sense it is a legend that refuses to go away.

Indeed, we can look back over other recent news reports about this so-called Black Knight. Apparently footage from a camera on board SpaceX's Falcon 9 missile in November last year picked up on a rock-like object darting through the atmosphere, prompting a YouTube video and fevered online speculation. Meanwhile, earlier last year a clip from a live stream of the Moon claimed to show an extraterrestrial object in near-polar orbit of the Earth, again sparking energetic web-based chatter. "Hubble? Google? Black Knight?" ran the title of that particular video. But just what have people been seeing?

In some cases, nothing. A lot of the earliest discoveries that have come to be linked to the Black Knight satellite theory relate to radio signals, as we will soon see. Yet a series of images from 1998 emerged that really threw the celestial cat among the pigeons. They were taken during STS-88, which was the first Space Shuttle mission to the International Space Station. There, for all to see, were images released by NASA that showed a black object hovering above the Earth in low orbit. And it wasn't long after the images were thrust in front of a hopeful public before people were performing some conspiratorial sums and sharing them with the wider world.

Proof indeed that the Black Knight existed and was hovering over us, watching our every move before reporting back to alien civilisations? Well, things are never quite so straightforward. While this particular object looked intriguing enough - you can very easily see how this black, irregular-shaped object could appear to be a mysterious alien probe as it tumbled through space - a couple of things were happening round about that time to cast serious doubts on any outlandish claims.

By way of explanation, astronaut Jerry Ross pointed out that the International Space Station was in the midst of being constructed when the images were taken. The US team, he says, was on its way to attach the American module to the one created by the Russians and, as part of that work, they had taken four trunnion pin thermal covers

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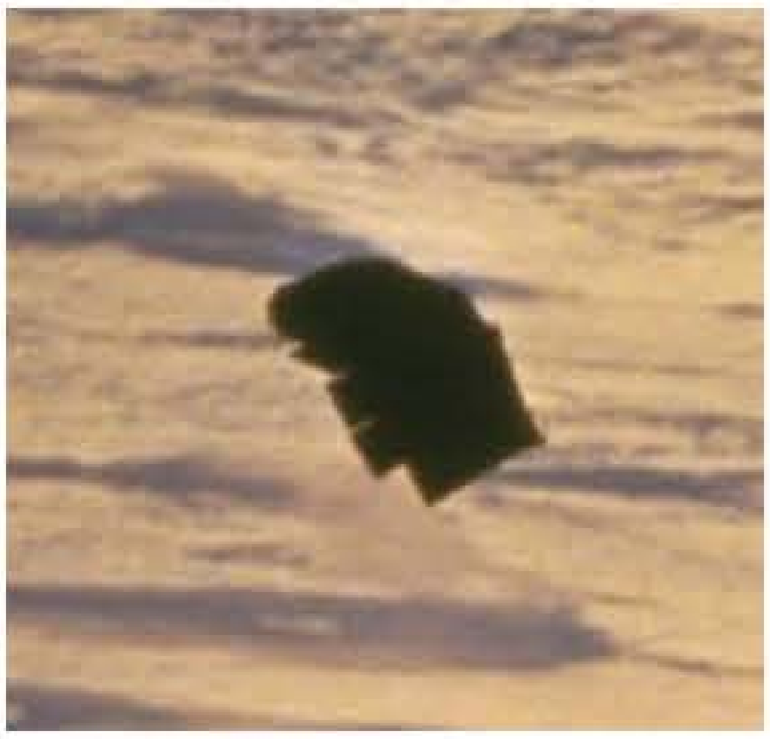


Top: So small, and yet the impact of images such as this on the Black Knight legend have been huge

Bottom left: A thermal cover is said to have been lost from the International Space Station on mission STS-88

Far left: NASA has stated that the Black Knight satellite is likely space debris, specifically a thermal blanket lost during an EVA

Left: An image taken from STS-88, which some claim is an alien satellite called the Black Knight

with them. The task was to wrap these around four bare trunnion pins, these being rods that attached the module to the shuttle while it was being transported. This would act to prevent heat loss from the exposed metal.

Unfortunately during one of the EVAs things went a little bit wrong and one of the covers came loose from its tether, causing the cover to float away along with some other items. "Jerry, one of the thermal covers got away from you," said commander Robert Cabana, and it soon became apparent that they wouldn't be getting it back. Subsequently captured on camera, this black object was given the object number 025570 by NASA, and a few days later the object fell from orbit and burned up. Far from being an extraterrestrial object, the black item floating in space was nothing more than a blanket.

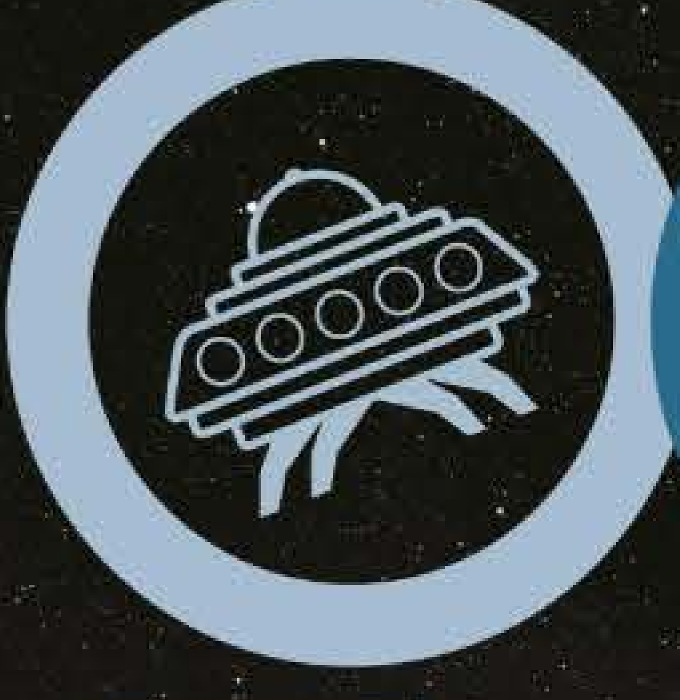
Much of this has been placed on the record. Former NASA space engineer James Oberg, who personally knows Ross and the person who took the photos, Sergei Krikalev, has gone to great lengths to show that these supposed images of the Black Knight have less fanciful origins.

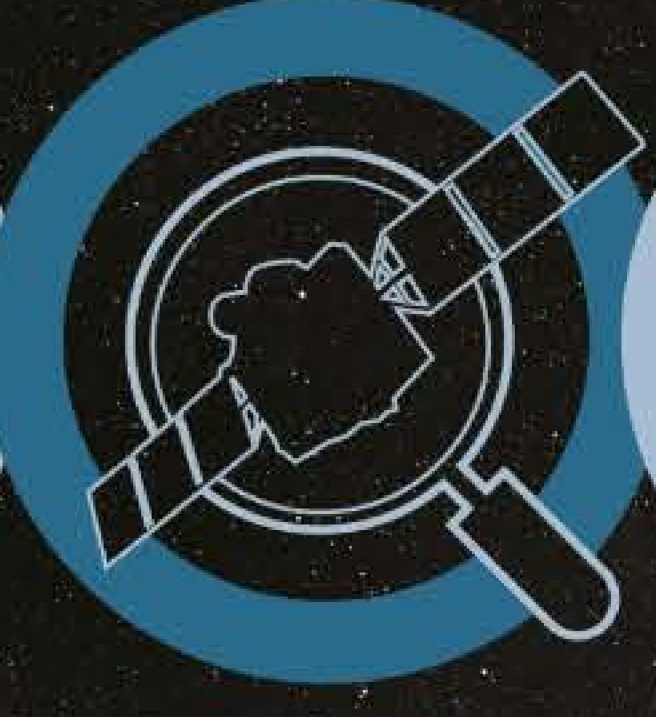
"Before leaving NASA I led the trajectory design team that produced the mission profile," he tells us. "Every step of the way there is consistency with what I learned as a lifelong spaceflight operations

"Images released by NASA showed a black object hovering in orbit"

Theories: Explaining the Black Knight satellite

Is the truth really out there? There have been many competing suspicions





Alien spacecraft

Search for 'STS-88 UFO' on YouTube and you'll get over 1,370 results promoting the possibility that the object photographed during this space shuttle mission was indeed extraterrestrial.

Spy satellite

In 1960 reports suggested the US Navy had caught sight of a 'dark' (presumably Soviet) spy satellite. America later claimed it was the remains of an Air Force Discoverer satellite.

Ancient human creation

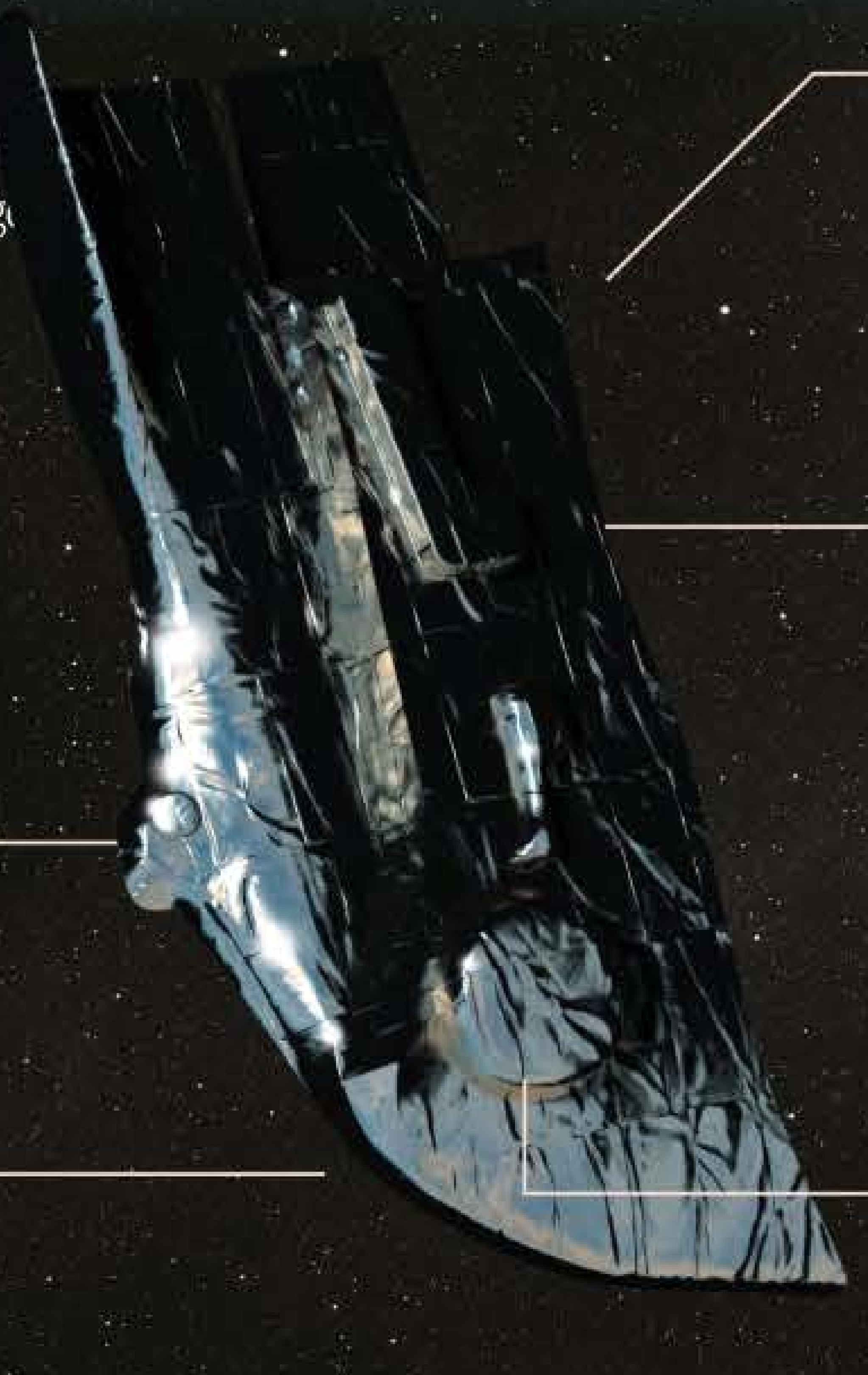
There is a theory that the Black Knight satellite was put into space by a previous advanced human civilisation or even an ancient intelligent animal species to watch over our evolution.

A British rocket

There was actually a research ballistic missile called Black Knight which made its first flight in 1958, but conspiracy theorists don't think it has anything to do with the assumed mysterious satellite.

Astronaut debris: what it's likely to be

When STS-88 took photos of a strange object, did it really confirm the existence of Black Knight?



How it ended up in space
During a spacewalk on mission STS-88, Jerry Ross and Jim Newman were installing a thermal cover on the International Space Station. Ross dropped it and it floated away into space – is this what we see here?

Why did it change form?
When the thermal cover was dropped, it tumbled. This constant rotation is why the photos show it at different angles. This is one of them.

Accounting for its odd shape
The thermal cover was irregularly shaped and it was crumpled. The reflective side is facing space, which is why it looks black.

It was seen to move slowly
If it was a spacecraft or satellite moving in polar orbit then it would have been travelling at ten kilometres (6.2 miles) per second. That's far too fast for the number of images that were taken.

Has it been seen since?
It was said to have been destroyed just a week later when it dropped into lower orbits, thanks to differential drag sucking its kinetic energy.

You can see bright highlights
The highlights are the shiny reflective parts being caught by light and then picked up by the camera.

specialist: why the blankets were needed, why one of them came loose, why it floated off the way it did. The difference is, for the general public all these features are unearthly to folks who are only familiar with Earthside principles of heating, working, motion and dozens of other never-before-encountered-in-history aspects of outer space." Given Oberg's debunking you'd think the matter would have drawn to a close. But no. Since the images were shared far and wide, conspiracy theories have continued.

"They are probably some of the weirdest-looking 70mm photos to ever come out of the space shuttle program," admits Oberg. "And apparently a NASA website update made the original links inoperative, sparking concerns over a cover-up. All normal journalistic practices – determining the timeline, asking witnesses, searching for the wider context – were skipped."

By absorbing the images into a growing body of 'evidence', they were seen as definite proof that the Black Knight alien satellite really was out there. Reaching that conclusion, however, has required greats leaps of faith, and has also needed past discoveries to be forced into the overall story. Indeed, firm believers have had no problems going right back to 1899 in pursuit of such 'truth' but, just like the photographic records, each piece of supposed evidence brought to the table so far has been explained away without falling back on the Black Knight myth.

So what happened in 1899? Well, that year Nikola Tesla began to record some very odd signals, seemingly from outer space. The accomplished Serbian-American electrical engineer had a passion for wireless technology, and he was in the early throes of an experimental wireless transmission station called Wardenclyffe Tower in Shoreham, New York. While in his barn-like laboratory in Colorado Springs, he noted the unusual signals and speculated they had come from another planet, a claim greeted with disbelief and scepticism.

Tesla's genius, however, meant the proclamation couldn't be entirely dismissed. This was, after all, the man who invented the first radio and the system of electric power distribution that we continue to use today, and the fact that the sounds were rhythmic and regularly patterned was certainly something to note. Tesla believed this rat-a-tat of signals was indicative of numbers, and that they were being used for communication. Yet although there have been suggestions that he was actually detecting radio waves from pulsars, NASA JPL scientist Varoujan Gorjian tells us there was "no chance" that happened.

"The very first source of non-terrestrial radio waves was discovered in the 1930s, and that was from the centre of our galaxy, which is the most powerful radio source in the sky at many frequencies," he explains. "It wasn't until the 1960s that the technology evolved to detect the first pulsars."

Battling space junk: could the Black Knight have posed a problem?

"No. Something like a trunnion pin cover has so much atmospheric drag because it is floppy, rather than dense, that it loses altitude quickly due to friction with the atmosphere. It was unlikely to come back and hit the International Space Station (ISS), and because there are very few satellites below the ISS there wasn't much risk there either. It would have burnt up completely on re-entry into the atmosphere."

Jonathan McDowell, astrophysicist at the Harvard-Smithsonian Center for Astrophysics

© NASA; ESA; Adrian Mann

Yet that doesn't mean the signal was alien. "Radio emissions from Earth were the cause of the first investigations into radio interference for transatlantic communication," Gorjian adds. "So if what Tesla detected was a real signal and not an artefact of his instrument, it most likely came from Earth." Even so, the idea of something more mysterious stuck, and it eventually formed part of wider 'evidence' pointing towards a conspiracy. People used Tesla's findings to bolster claims for the Black Knight. They also took on board the work of a Norwegian engineer called Jørgen Hals, who found that radio signals he transmitted were being echoed back to him a few seconds later. We now know these as long delayed echoes, and Hals was indeed the first person to observe them. The fact that we don't have a confirmed explanation of their cause, however, has been seized upon: in 1973, Duncan Lunan wrote an article in *Spaceflight* magazine suggesting those studying long delayed echoes had overlooked the possibility they were sent by an alien space probe.

His theory built upon the work of Stanford University radio science engineer Professor Ronald Bracewell, who proposed the echoes may have been signals taken from Earth and rebroadcast by alien satellites. Lunan said he'd identified a hidden radio message sent by the inhabitants of a planet orbiting Epsilon Boötis, although he withdrew this three years later. "The two stars are too massive and too short-lived for life to have evolved there," he tells us.

Yet he still has faith in an extraterrestrial explanation for the recordings. "The changes in the long distance echo patterns in apparent response to changes in the outgoing signals from Earth really do look like the responses of a Bracewell probe, and there is still no satisfactory natural explanation for the phenomenon," he says. But he says if the long distance echoes were deliberately produced by a probe, there's a problem in that they stopped in 1975.

"If a probe was monitoring Earth, rather than trying to attract attention, perhaps it belatedly discovered from the 1973 to 1974 publicity that it had given away its presence in the 1920s and pulled out in 1975. That's the only explanation I can see for its apparent departure." And yet, for all of that, he says his research has nothing to do with the "Black Knight nonsense". If there is a link between his theory and the Black Knight, it is not one that is being made by him.

The effect of a collision and debris on Mir's solar arrays after a decade in orbit

Danger zone: historic problems with space debris

From dodging forgotten satellites to recovering radioactive debris, space junk endangers life on Earth and in space

Kosmos 954 incident

A nuclear-powered Soviet reconnaissance satellite deviated from its orbit and re-entered the atmosphere over Canada on 24 January 1978, depositing radioactive debris over around 124,300 square kilometres (48,000 square miles). As part of Operation Morning Light, a team recovered debris which included fragments whose radioactivity could kill a human within hours. The incident led to the Soviets paying Canada C$3 million in compensation in 1981.

STS-48 debris avoidance manoeuvre

In September 1991 the crew of Discovery were forced to perform the first collision avoidance manoeuvre when it became apparent that debris from a Soviet Kosmos 955 satellite might pass within 1.1 kilometres (0.7 miles) of their position. The Shuttle's thrusters fired for seven seconds, creating a larger separation distance of 16 kilometres (ten miles). "I didn't look out the window to see if I could see the intruder go by," said STS-48 astronaut Ken Reightler. "I just wanted to make sure we didn't make the news back home!"

Chinese anti-satellite test

In a troubling incident, China launched a ballistic missile on 11 January 2007, intentionally destroying the ageing Fēngyún-1C weather satellite at an altitude of 862 kilometres (536 miles). Although the US and the Soviet Union had previously performed anti-satellite tests, this event was a significant space junk contributor, creating over 3,300 pieces of trackable debris and 150,000 particulates, and increasing to the US Space Surveillance Network catalogue by 25 per cent. 85 per cent of the debris remains in orbit.

Iridium 33/Kosmos 2251 collision

Some 789 kilometres (490 miles) above Siberia on 10 February 2009, an US operational communication satellite, Iridium 33, impacted Russia's out-of-service Kosmos 2251 satellite at a speed of 11 kilometres (6.8 miles) per second. In an event whose probability was one in 50 million, both were destroyed in the first-ever accidental satellite collision. Over 1,000 fragments larger than ten centimetres (four inches) were generated and Shuttle Atlantis' 2009 visit to the Hubble Space Telescope was at risk. Along with Fēngyún-1C, they represent a third of all catalogued debris in low-Earth orbit. A small piece of junk passed within 14 kilometres (nine miles) of the ISS in 2012.

ISS debris event

Remarkably, the ISS Cupola – which provides a unique, seven-window observation deck – has sustained little damage from space junk since its arrival in 2010. Although the windows have retractable shutters, the fused silica and borosilicate glass has suffered several chips and dents, first in 2012 and more recently in 2016. British astronaut Tim Peake photographed a 7-millimetre (0.28-inch) depression, likely caused by a paint fleck or a shard of metal. "Glad it's quadruple-glazed," he quipped.

Plans to clean up space junk

It's an ever-increasing problem, but many organisations are working on solutions

KITE

In January 2017 a 0.8-kilometre (0.5-mile) metal tether built by the Japanese Aerospace Exploration Agency and a fishing-net manufacturer awaited deployment from the H-II Transfer Vehicle. Known as the Kounotori Integrated Tether Experiment (KITE), its main objectives were to demonstrate the ability to extend an uncoated bare-tether in space and evaluate the capability to support electric currents and slow down and deorbit debris. Sadly, problems with deployment led to its cancellation, but KITE showed great promise for a 'propellantless' active removal of space junk.

Laser broom

Intended to alter the orbit of space junk and induce re-entry, the use of a ground-based 'laser broom' was investigated by the US Air Force in the 1990s as part of Project Orion. It would impose sufficient thrust on the target to increase atmospheric drag. A 2011 NASA study indicated that repeated high-power laser impingements could alter the course of a piece of debris by one millimetre (0.04 inches) per second, causing it to re-enter the atmosphere or be prevented from hitting another craft. Conversely, though, it has been argued that laser brooms risk fragmenting debris into smaller pieces.

CleanSpace One and e.Deorbit

CleanSpace One and e.Deorbit aim to capture defunct satellites, collapsing conical 'nets' around them. The former will pluck the SwissCube satellite from orbit, while the latter will remove a derelict polar-orbiting satellite. Both missions will employ high-dynamic-range rendezvous cameras, propulsion assets and real-time imaging software. Mechanised claws were considered for CleanSpace One, but since the SwissCube may be spinning, a student-designed net was adopted. A similar approach, combined with robotic 'tentacles', was also advanced for e.Deorbit.

So why does this talk of the Black Knight satellite persist? Perhaps because there have been more mysteries for conspiracy theorists and UFOlogists to pick up on. One such researcher was Donald Keyhoe, an American Marine Corps naval aviator who worked at a time when flying saucers were becoming staples of the cinema and popular culture. Keyhoe wrote an article called *Flying Saucers Are Real* for *True* magazine in 1949, spun it off into a half-million selling book and suggested the US Air Force was aware UFOs existed.

Keyhoe also reported that the US Air Force had detected a couple of satellites orbiting the Earth in 1954. Not only that, they were in retrograde orbit, which means they were said to be travelling east to west, against the direction of Earth's rotation, rather than the more common prograde motion of west to east. Artificial satellites tend to be prograde because retrograde orbits require extra velocity and propellent, but what made Keyhoe's reporting even more odd is that he was reporting at a time when the technology to launch satellites had not seemingly evolved. What's more they were in polar orbit – again strange given that all satellites prior to 1960 had been put into equatorial orbit.

Now things were heating up. On 11 February 1960 it was reported that the US Navy saw what it thought was a Soviet spy satellite, causing unease across the US. A few weeks later, amid chatter that it wasn't a Soviet object at all, the object was identified as the remains of a Discoverer VIII satellite that had gone astray. Then it began to emerge that astronaut Gordon Cooper had reported seeing a UFO during his 15th orbit in Mercury 9 in 1963. Even though he denied this – it was said to be a greenish object with a red tail – he did stand by seeing a strange encounter in Germany in the 1950s. Later, Black Knight theorists would include such tales within their body of evidence.

Certainly, talk of the Black Knight has gathered pace over the past 50 or so years, and some people refuse to believe that it's anything other than extraterrestrial. They will discuss this supposed alien anomaly's purpose, and some will refuse to accept reasoned explanation. There have been 6,000 or so human-made satellites launched since 1957, but this one continues to be the focus of fevered speculation – hence numerous YouTube videos, a little bit of Photoshopping and outlandish news talk.

"The main impression is that internet hucksters will make any claim that will draw money-making 'hits' to their websites, and that far too many internet surfers are desperate to find and cling to bogus 'secrets' to allow them to pretend they are smarter than the 'sheeple' who surround them at home, in school or at work," Oberg says. One thing's for sure, we haven't heard the last of the Black Knight: it's just waiting for more 'evidence' to emerge.

A Delta II upper-stage motor fragment crashed in the Saudi Arabian desert in January 2001

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Moon Profile

Titan

Saturn's moon is a harsh, uninhabitable world, yet has uncanny similarities to our home planet

Titan is one of the most intriguing moons in our Solar System. From the outside astronomers see a ball of golden-orange haze, but it's what's hiding beneath this atmosphere that intrigues – a freezing world with bodies of liquid. Planetary scientists are fascinated by Titan and its unusual contents.

Titan, the largest moon of Saturn and second-largest moon in the Solar System behind Jupiter's Ganymede, is an icy ball that stretches out to almost 5,150 kilometres (3,200 miles) in diameter, nearly 50 per cent wider than the Earth's Moon. Due to Saturn's position, which is around 1.4 billion kilometres (870 million miles) from the Sun, nine-times farther than Earth's average distance, its satellite Titan receives sunlight that is 100-times fainter than the light on Earth. This freezing world may be one that is inhospitable for humans, but there are bodies of liquid present on the surface. These observations have been the subject of many studies throughout the decades.

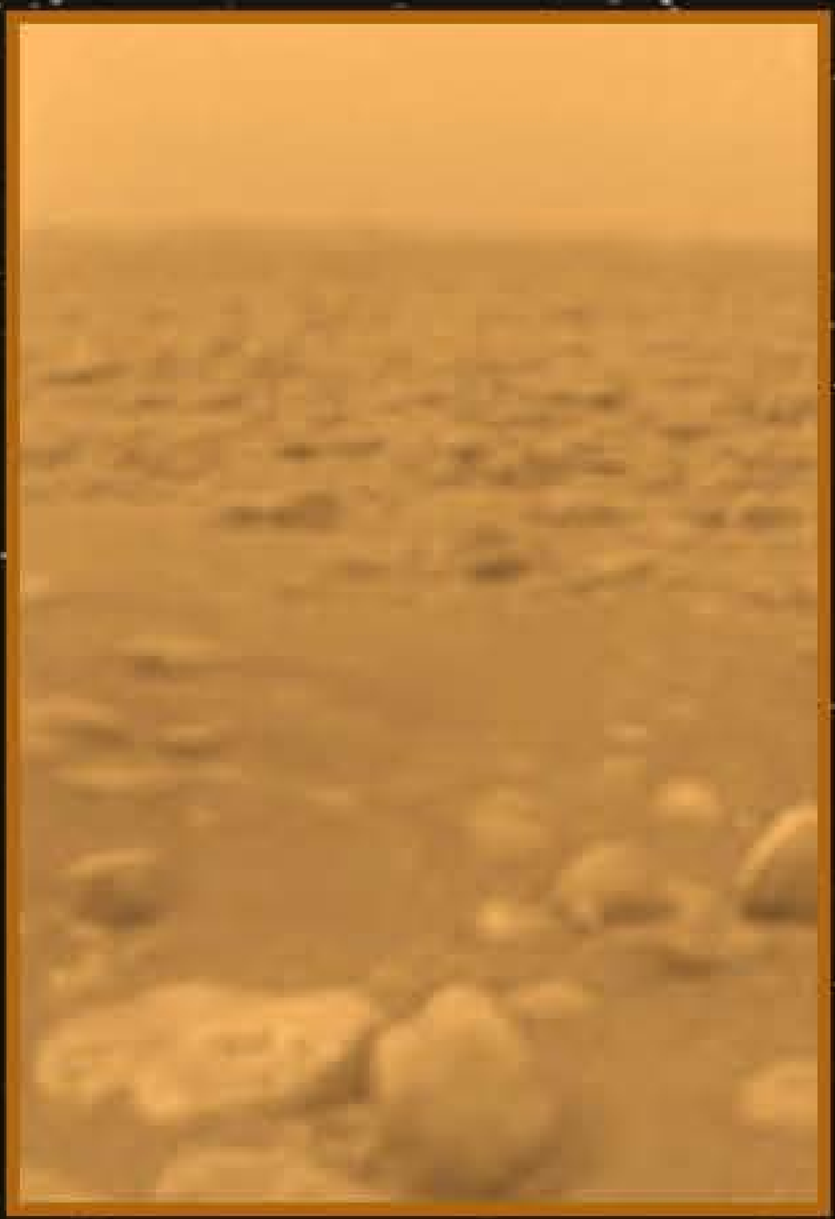
Although there are many interesting moons in the Solar System, Titan is the most Earth-like: it has an atmosphere and it is rocky, but also has bodies of liquid on the surface with a rain cycle replenishing them. All of this happens on a moon that has a surface temperature of minus 179 degrees Celsius (minus 290 degrees Fahrenheit); there obviously isn't water on Titan as that would have been frozen. These lakes, rivers and seas are filled with liquid hydrocarbons such as methane and ethane. These complex molecules are capable of existing as a liquid in such a cold temperature.

As for the atmosphere – in fact, Titan is the only moon with a thick atmosphere in the Solar System – it has an atmospheric pressure 60 per cent greater than that of the Earth. This would feel the same as swimming 15 metres (50 feet) below the surface in an ocean on Earth. This atmosphere is comprised mostly of nitrogen, with a whopping 95 per cent. Around five per cent is methane and the extremely small remainder is carbon-rich compounds. This provides the orange haze that is seen from afar.

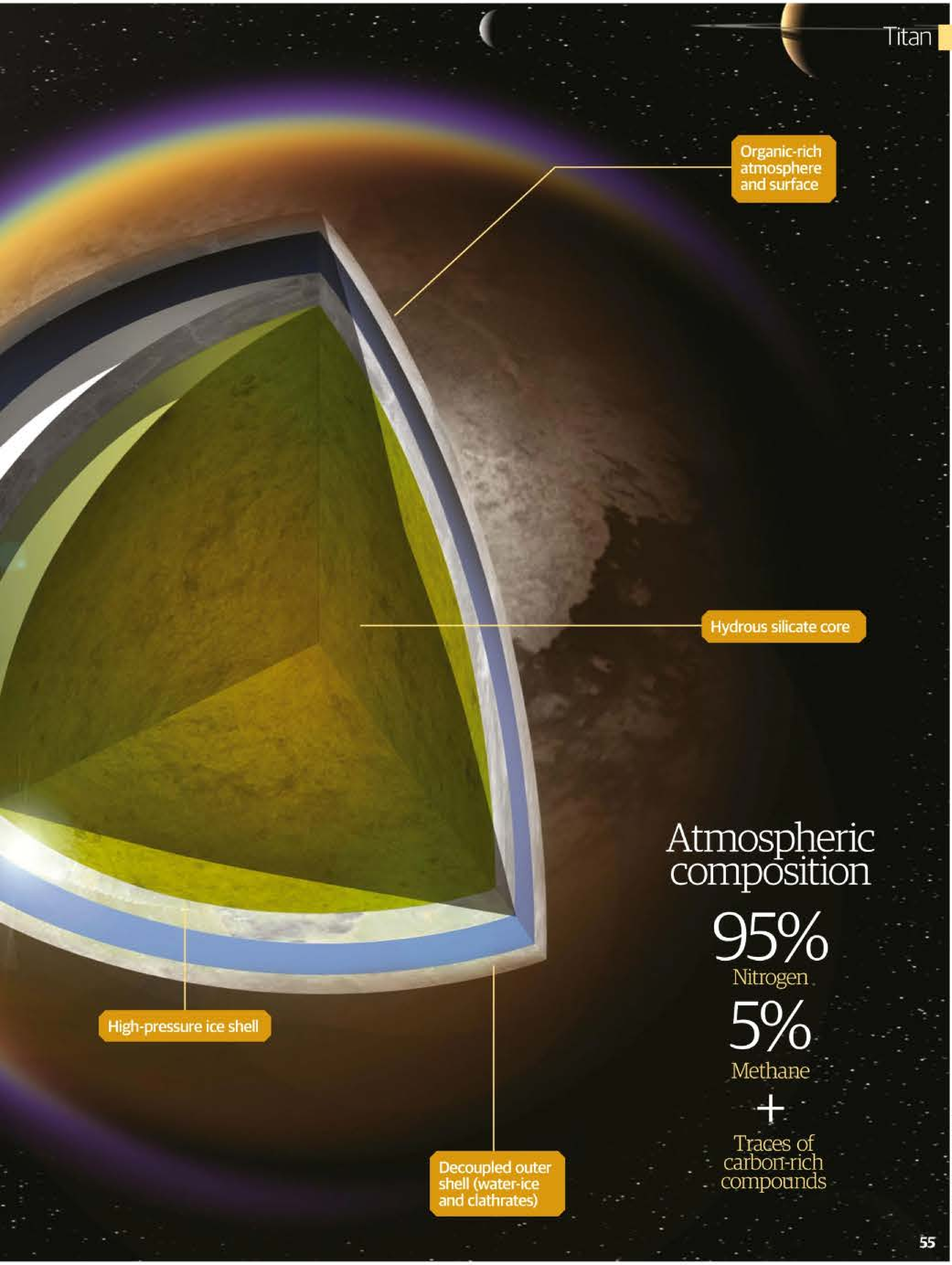
The presence of an atmosphere and surface liquid means there is a cycle of evaporation and condensation, creating clouds of methane ice and cyanide gas and precipitation in the form of methane rain. A moon with a weather cycle is unusual, and astronomers are amazed at how the Earth's water cycle can be applied to a distant, alien world.

There is a mystery about Titan that astronomers can't seem to explain with any conviction, and that's what is replenishing Titan's atmosphere. It is known that sunlight breaks up methane at the top of the moon's atmosphere, and scientists are wondering what is bringing more methane into the atmosphere in its place. One suggestion has been volcanic activity. The presence of volcanoes would be yet another amazing similarity between Titan and our home planet.

> "Titan has bodies of liquid on the surface with a rain cycle replenishing them"



Huygens sent back images of the Titanian surface to Cassini


Organic-rich atmosphere and surface
Hydrous silicate core
High-pressure ice shell
Decoupled outer shell (water-ice and clathrates)

Atmospheric composition

95%
Nitrogen

5%
Methane

+

Traces of carbon-rich compounds

© ESA/NASA/JPL, A. D. Fortes/UCL

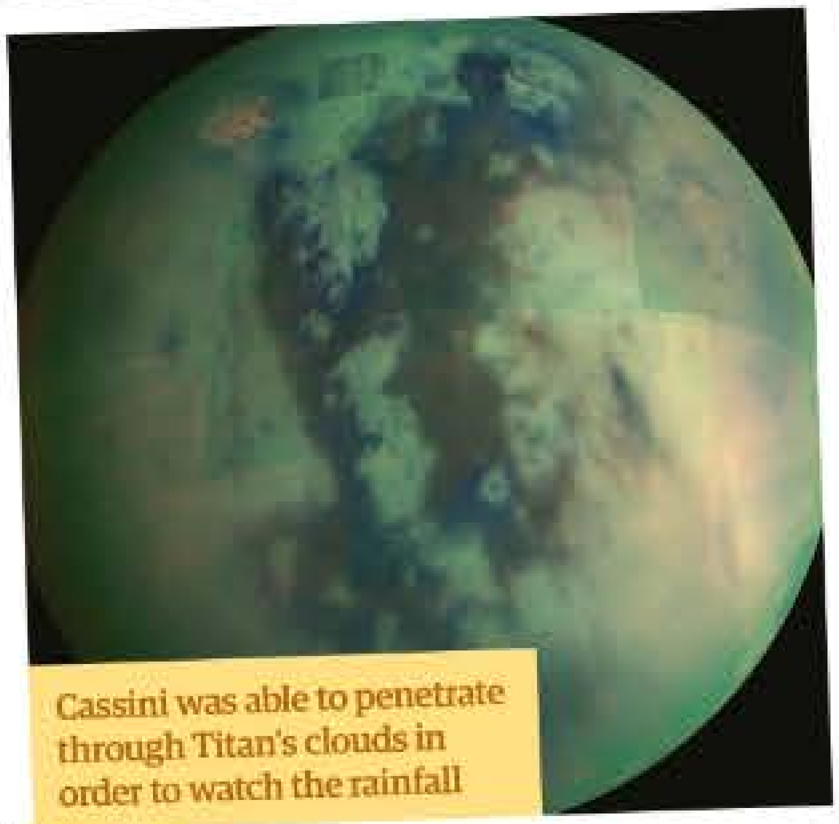
Titan catch-up

Understanding the atmosphere

Titan's atmosphere is an enigma. Ever since its discovery astronomers have been trying to explain how such a dense atmosphere and surface liquid arose and were preserved for millions of years. "Because Titan is the only moon in our Solar System with a substantial atmosphere, scientists have wondered for a long time what its source was," says Dr Kelly Miller, a research scientist at Southwest Research Institute in San Antonio, Texas, United States. "The main theory has been that ammonia ice from comets was converted, by impacts or photochemistry, into nitrogen to form Titan's atmosphere. While that may still be an important process, it neglects the effects of what we now know is a very substantial portion of comets: complex organic material."

But how is it replenished? Well, Miller believes this can be explained by 'cooking' organic materials brought to Titan via comets or other primitive objects during the moon's conception. When these materials are cooked, gases are released, and this is what is maintaining the levels of methane on Titan.

Astronomers also believe hydrogen ices could form atop the moon's lakes


Cassini was able to penetrate through Titan's clouds in order to watch the rainfall

Changing seasons

Much like seeing the seasons change from summer to winter on Earth, scientists have spotted signs of the changing seasons on Titan using valuable data from NASA's now-deceased Cassini spacecraft. Using pictures of the moon's northern hemisphere, Rajani Dhingra – a doctoral student in physics at the University of Idaho in Moscow, United States – and her team have seen rainfall on the north pole. The rainfall also provides the first indication of the beginning of a summer season.

"The whole Titan community has been looking forward to seeing clouds and rains on Titan's north pole, indicating the start of the northern summer, but despite what the climate models had predicted, we weren't even seeing any clouds," said Rajani Dhingra. "People called it the curious case of missing clouds."

Now that these images have been acquired and analysed the case of Titan's seasons has become a little bit clearer, courtesy of Cassini and its Visual and Infrared Mapping Spectrometer instrument. The spacecraft's near-infrared capabilities allow it to peer inside the atmosphere and observe this rainfall. Compared to Earth's yearly cycle of four seasons, a season on Titan lasts seven Earth years.

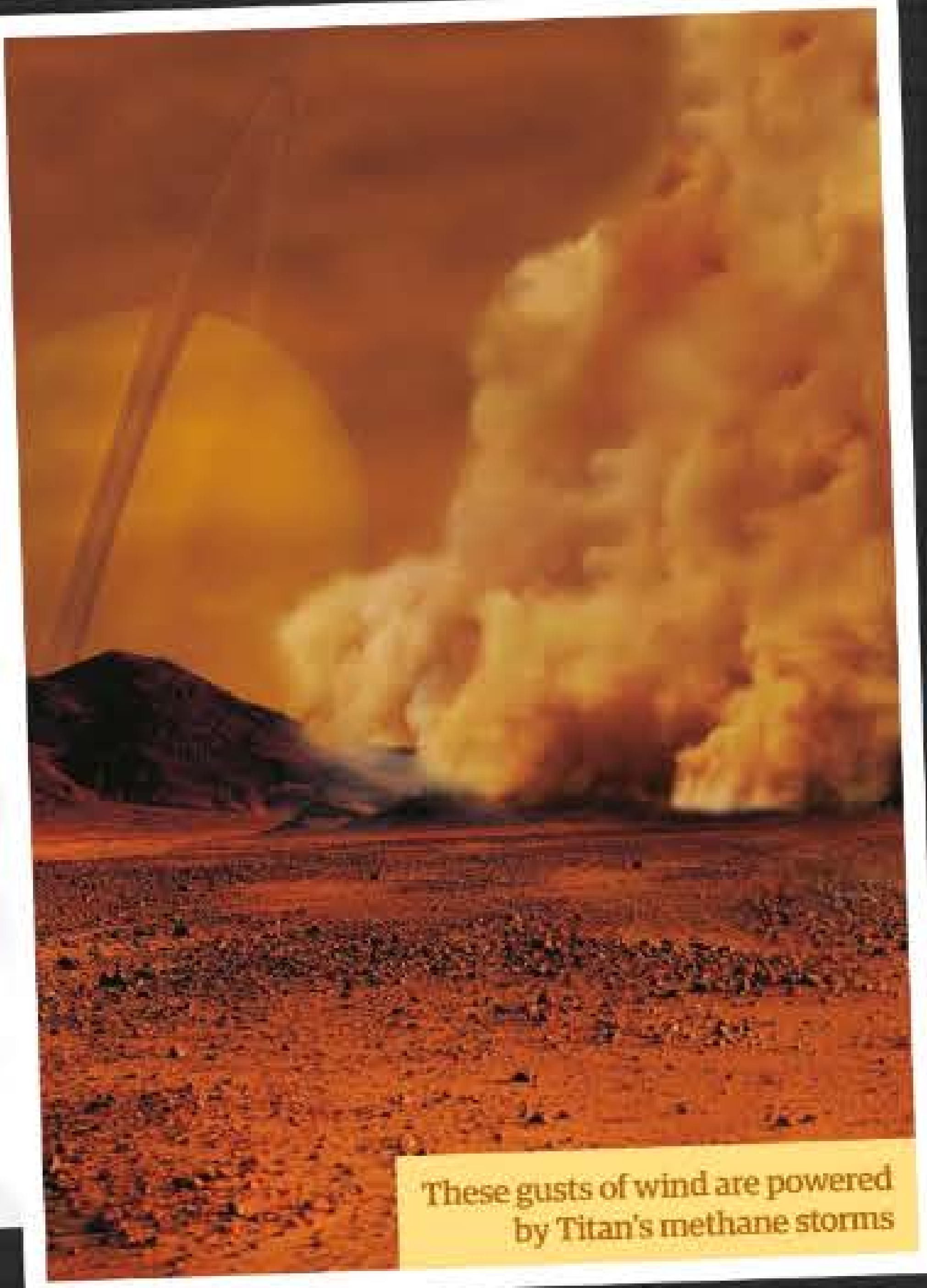
> "Scientists have spotted signs of the changing seasons on Titan using valuable data from NASA's now-deceased Cassini"

Dust storms sweeping the surface

If you didn't already think that Titan was a harsh enough environment, Cassini also spotted giant dust storms sweeping across the moon's surface. This observation raises intrigue as astronomers try to work out what is generating this powerful gust around the equatorial region.

"Titan is a very active moon," says Sébastien Rodriguez, an astronomer at the Université Paris Diderot, France. "We already know that about its geology and exotic hydrocarbon cycle. Now we can add another analogy with Earth and Mars: the active dust cycle in which organic dust can be raised from large dune fields around Titan's equator."

In the same way the weather changes with the seasons on Earth, the same occurs on Titan. In this case, when the Sun crosses Titan's equator massive clouds are formed in these tropical regions, creating powerful methane storms. This is what astronomers looking at this feature thought was occurring, but it turned out to be something completely different. After more modelling scientists discovered that these are actually clouds of organic molecules raised from the dune, and therefore the first observation of a dust storm on Titan.

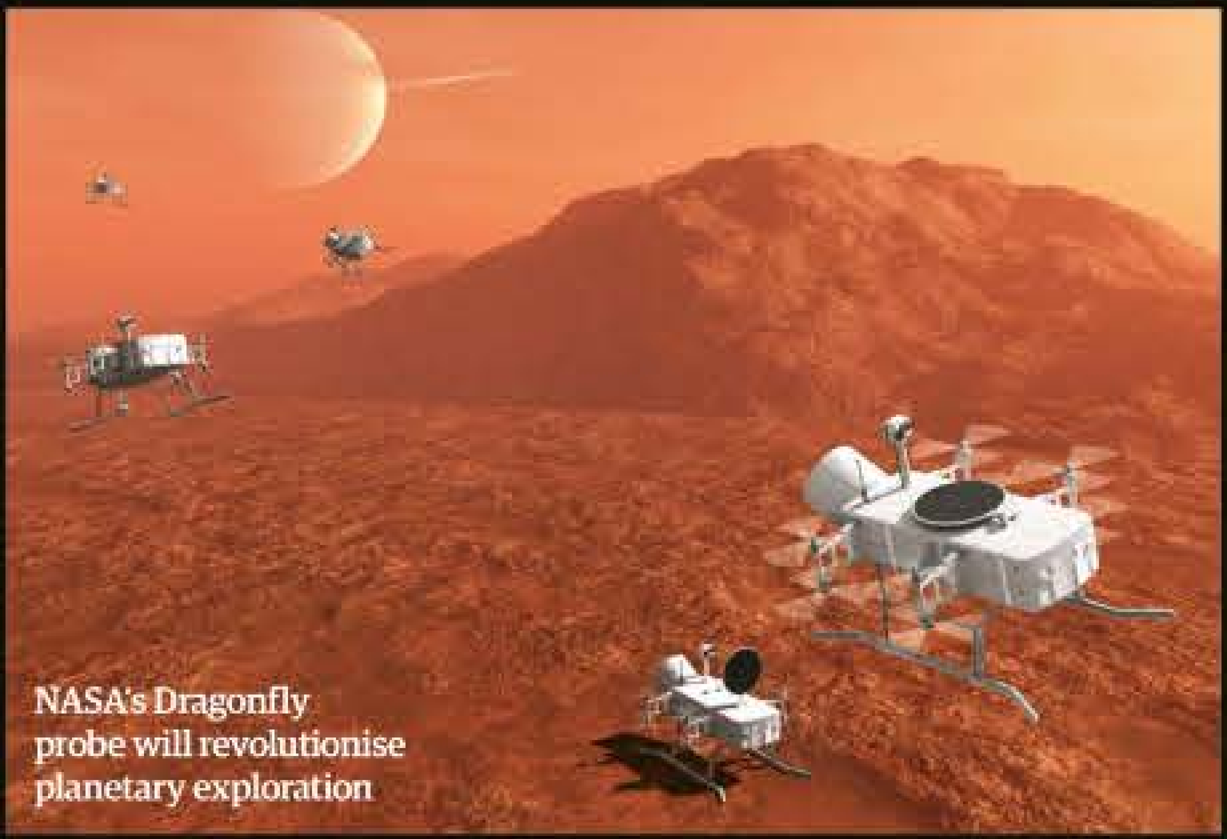

These gusts of wind are powered by Titan's methane storms

Mission to Titan

Titan isn't exactly a nearby neighbour we can pop to and see how it's doing, like Mars. When Earth and Saturn are closest to each other they are still 1.2 billion kilometres (746 million miles) apart. This means visits to Titan in the past have been few and far between. The first probe to visit the Saturnian system was NASA's Pioneer 11 in 1979, followed by Voyager 1 and 2 in 1980 and 1981 respectively. NASA's Voyager spacecraft were pivotal in making initial measurements of its physical properties such as mass, density, composition and so on. These observations caught the attention of many because of their irregularity.

The best spy sent to the Saturnian system, and in particular Titan, was the Cassini spacecraft and its accompanying Huygens lander, a collaborative mission between NASA, the ESA and ASI. Cassini-Huygens arrived at Saturn in July 2004 and made many observations of the moon before Huygens was released with the intention to burst through the hazy atmosphere of Titan and land on its surface. On 14 January 2005 Huygens made its successful descent onto Titan before its batteries died and communication ceased with Cassini. All observations of Titan after the fact were made by Cassini before it ended its mission by crashing into Saturn's atmosphere in September 2017. The data collected by Cassini is still providing new discoveries over a year after the mission's end.

There have been talks of sending more probes to the exciting moon using new and innovative ways. One idea that is in advanced discussion is the 'Dragonfly' lander, as part of NASA's New Frontiers program. The Dragonfly lander will not just sit on the surface like Huygens, it will be a dual-quadcopter drone capable of moving around Titan's thick and nitrogen-rich atmosphere. This would allow astronomers to get a closer look at different surface features and would allow more freedom in movement than a rover.



NASA's Dragonfly probe will revolutionise planetary exploration

Huygens' descent to Titan

Time*: 14 January 2005 10:13am UTC (11:13am CET)
Activity: Huygens reaches the top of Titan's atmosphere.

Time: 10:17am UTC (11:17am CET)
Activity: Pilot parachute deploys, and a minute later the front shield is released and transmission to Cassini begins.

Time: 10:32am (11:32am CET)
Activity: Main parachute separates and drogue parachute deploys to guide Huygens to the right spot.

Time: 11:57am UTC (12:57pm CET)
Activity: The Gas Chromatograph Mass Spectrometer begins sampling the atmosphere before it touches the ground.

Time: 12:34pm UTC (1:34pm CET)
Activity: Huygens makes a successful touchdown on Titan.

Time: 2:44pm UTC (3:44pm CET)
Activity: Cassini stops collecting Huygens data, thus concluding its work, and at 3:14pm UTC the first data is sent to Earth.

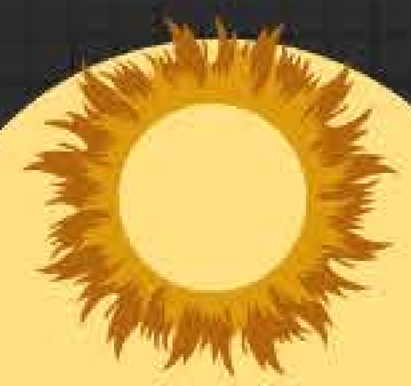
*All times above are Earth Received Time - i.e. 67 minutes after the event has happened at the spacecraft

Titan's facts and stats

600 KM

Titan's atmosphere extends about 600 kilometres (370 miles) above its surface.

Data suggests there could be the presence of a liquid ocean beneath the surface.



The conditions on Titan could become more hospitable when the temperature of the Sun increases 6 billion years from now.

2%

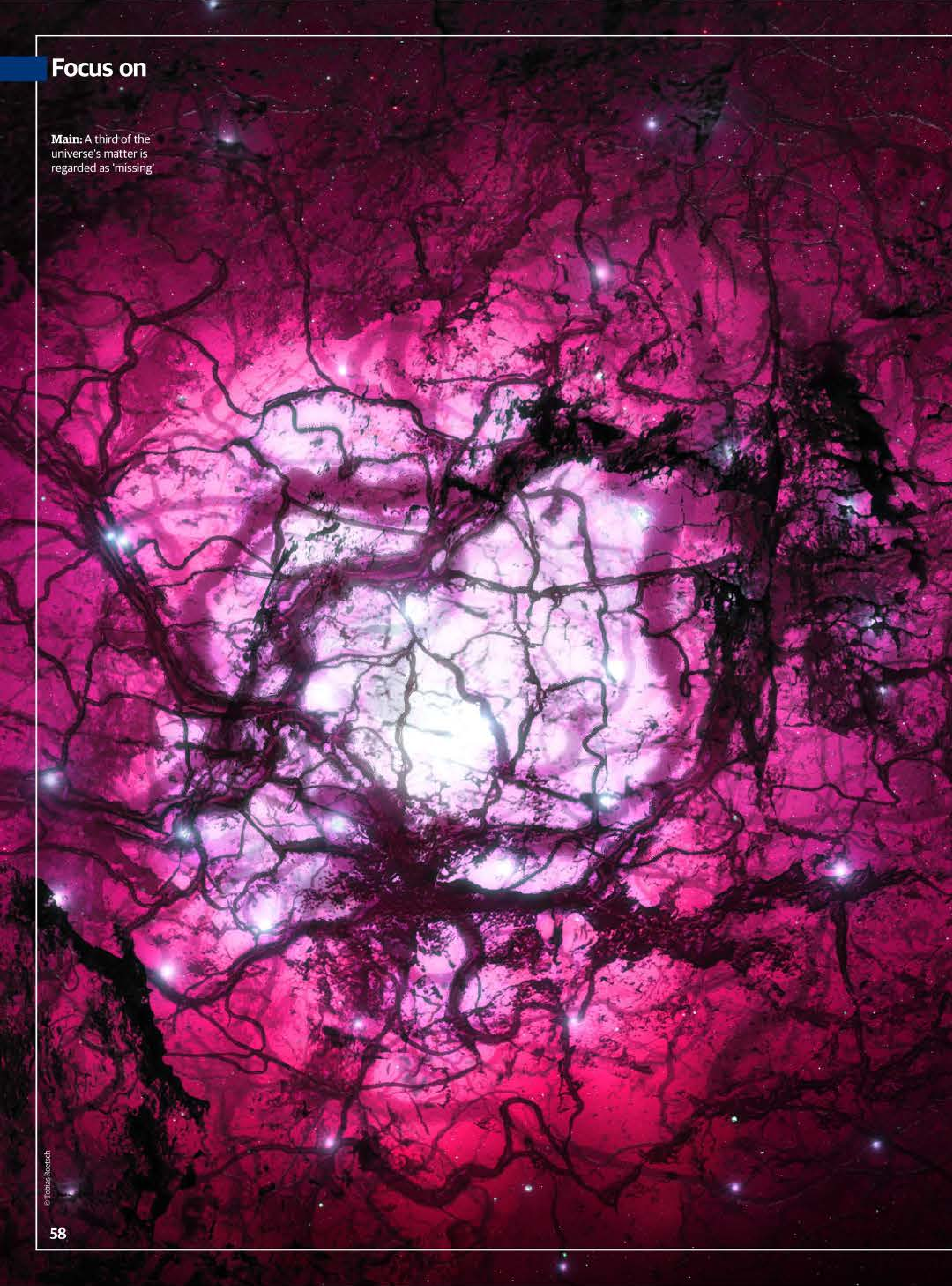
Jupiter's Ganymede is only two per cent larger, meaning there isn't much size between the two largest moons in the Solar System.

ESA's Huygens holds the record for most distant landing of a human-made probe.

Titan is tidally locked to Saturn, much like the Moon is to Earth, meaning only one side of Titan is facing Saturn at all times.

The 'sand' on Titan's dunes is composed of dark hydrocarbon grains that resemble coffee grounds.

© NASA/JPL; Caltech; UPGP; Adrian Mann



Main: A third of the universe's matter is regarded as 'missing'

© Tobias Roetsch

HAVE WE FOUND SPACE'S MISSING MATTER?

A third of the cosmos is in hiding – and astronomers think they might know where it has gone

Reported by Lee Cavendish

Looking into the depths of space reveals a plethora of galaxies: an enormous collection of stars, black holes, gas and dust scattered throughout the entire universe. Yet all of this is still not able to explain a third of all 'normal' matter that appears hidden from us. When astronomers use the term 'normal' matter, they are talking about the matter that makes up everything we see, such as hydrogen, helium and other elements, and not the mysterious dark matter. Recently, NASA's Chandra X-ray Observatory has been trying to win this cosmic game of hide-and-seek, and may have found an important clue.

You may be thinking how astronomers can know that a third of the mass is missing if they can't even see it. Well, these astronomers are confident in the observations and calculations they have made and estimates of the amount of normal matter expelled from the Big Bang 13.8 billion years ago. The issue is that these observations and calculations can only locate two-thirds of the matter.

One theory behind this smoke-and-mirrors act is that the matter is hidden in enormous strands, or filaments, of warm (temperatures less than 100,000 Kelvin) and hot (temperatures greater than 100,000 Kelvin) gas in intergalactic space. These filaments are more commonly known as warm-hot intergalactic medium (WHIM) and are invisible in optical light, but they have been observed in ultraviolet. Simulations have suggested they appear to look like a cosmic web of hot, diffuse gas.

However, it is Chandra's X-ray abilities that have led to the development of a new technique that has presented strong evidence for the hot component. "Our technique is similar in principle to how you might conduct an efficient search for animals in the vast plains of Africa," says Akos Bogdan from the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, United States. "We know that animals need to drink, so it makes sense to search around watering holes first."

An unusual concept when taken out of context, but the idea behind the technique is from when Chandra observed a highly energetic pulsar 3.5 billion light years away from Earth. This pulsar emits light easily detectable by Chandra, and with this unique ability the telescope will also be able to detect any hidden WHIM filaments obstructing the light's path. Any WHIM filament in the way will absorb some of the pulsar's light – this is what is meant by watching an animal drink to locate it.

By the end of the analysis the team had identified 17 possible WHIM filaments between Earth and the pulsar by detecting oxygen. The oxygen in this case showed characteristics that it was in a gas that had a temperature of about one million degrees Kelvin. By extrapolating the results to the other known elements across the observable universe, astronomers suggest that this could be the long-awaited explanation to the missing matter issue.

> "One theory behind this smoke-and-mirrors act is that the matter is hidden in strands of warm and hot gas"

5,498 DAYS ON MARS

OPPORTUNITY'S GREATEST HITS

It caused scientists to sing with joy as one breakthrough unfolded after another - we remember the best moments of Mars' longest-serving rover

Reported by David Crookes

FREE OPPORTUNITY POSTER INSIDE

For almost 15 years the Opportunity rover explored the Martian surface, helping scientists to make stunning breakthroughs and sending back tens of thousands of images which shone fresh light on the Red Planet. When it informed NASA that its batteries were running low, however, many feared the worst.

Despite sending over 1,000 commands, engineers from the Space Flight Operations Facility at NASA's Jet Propulsion Laboratory found they simply couldn't rouse the robot. A dust storm on Mars had proven too much, it seemed, and it ensured that as of 10 June 2018, nobody heard from Opportunity again.

But that's not to say the rover's memory doesn't live on. Its value to science has been huge and it appears rather apt that it would fail at Perseverance Valley, given its longevity. Poignantly, the final attempt to wake it came with a rendition of the Billie Holiday song, *I'll be seeing you*. Here we look at its greatest moments since 2004.

© NASA/JPL-Caltech

OPPORTUNITY'S MAIN GOALS

☑ To last three months

Opportunity's mission should have lasted 92.5 Earth days – it went on for 5,498!

☑ Find past water activity

Opportunity was to look for and analyse soil and rocks for signs of water.

☑ Figure rock, mineral and soil composition

It determined the composition and distribution of these materials at its landing site – and further afield.

☑ Determine geologic processes

Opportunity studied the geology of more than 100 impact craters and examined their formation and erosion.

☑ Validate observations made by orbiter

The rover could use its many instruments to collect and study samples, confirming what the Mars Reconnaissance Orbiter had observed.

☑ Search for iron-containing minerals

Opportunity found rocks rich in iron and magnesium at Comanche.

☑ Characterise rock and soil mineralogy

Straight away Opportunity discovered hematite, and it went on to make more breakthroughs.

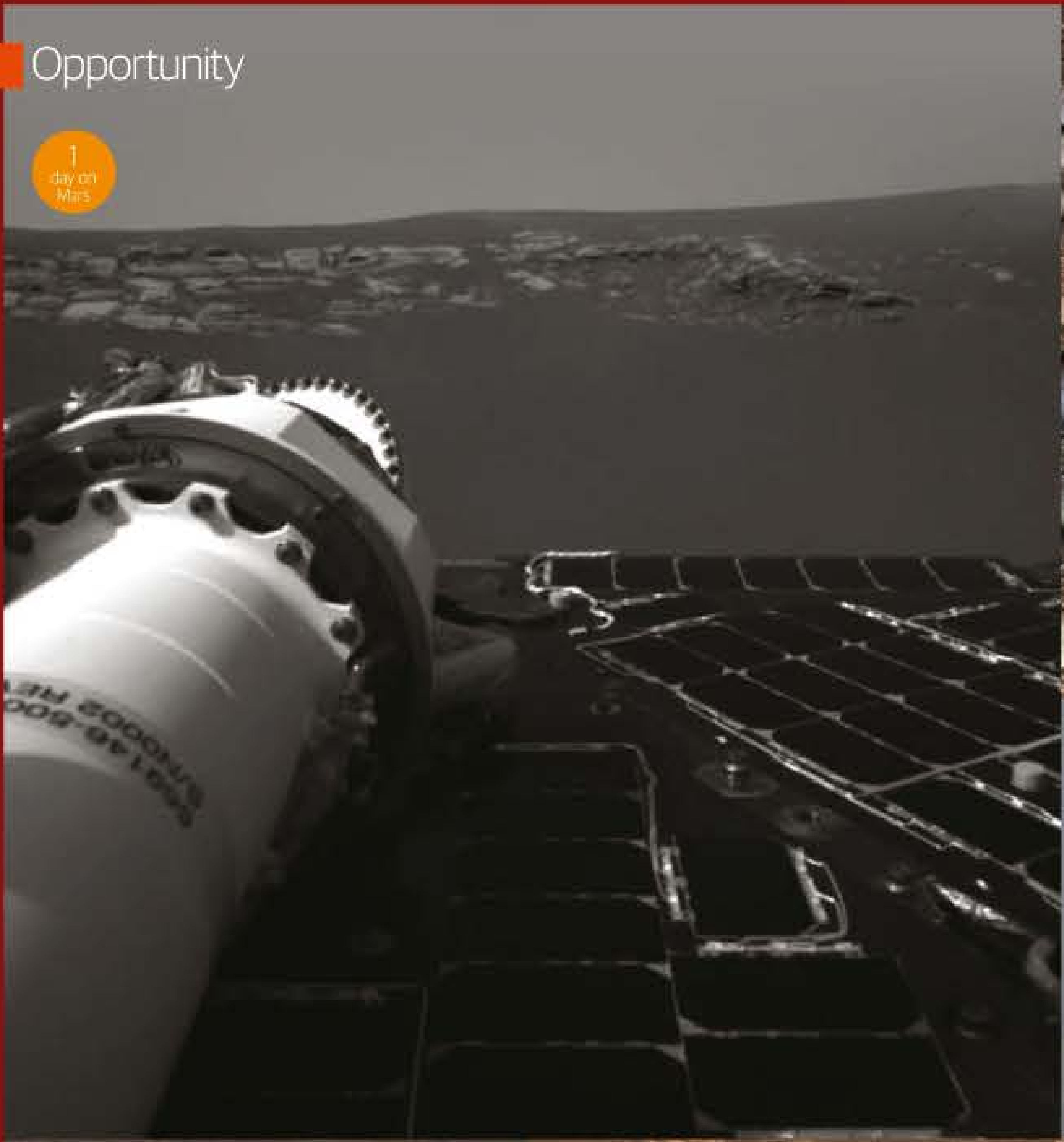
☑ Discover environmental conditions

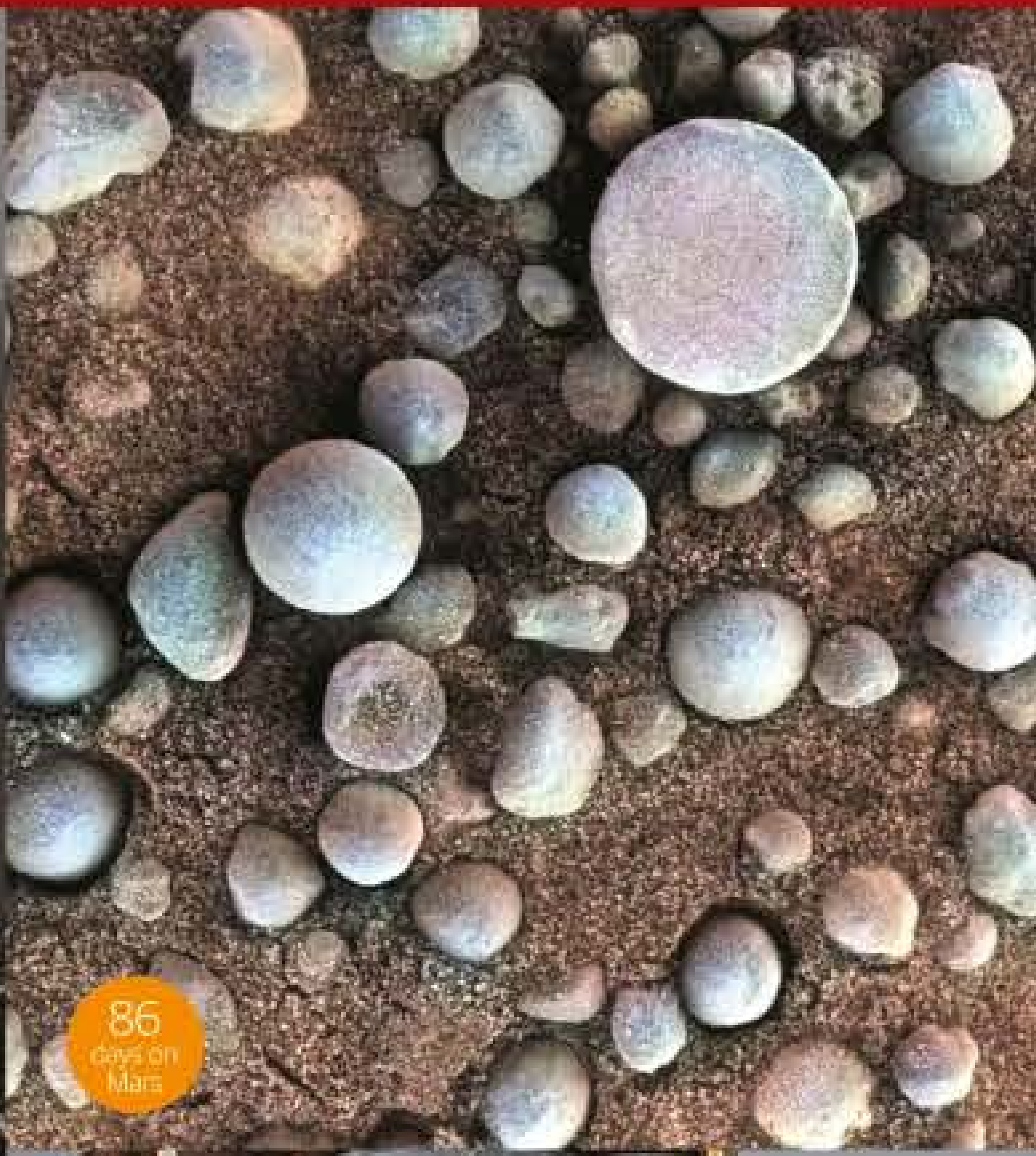
The composition of the rocks gave strong clues as to the make-up of the atmosphere when water was present.

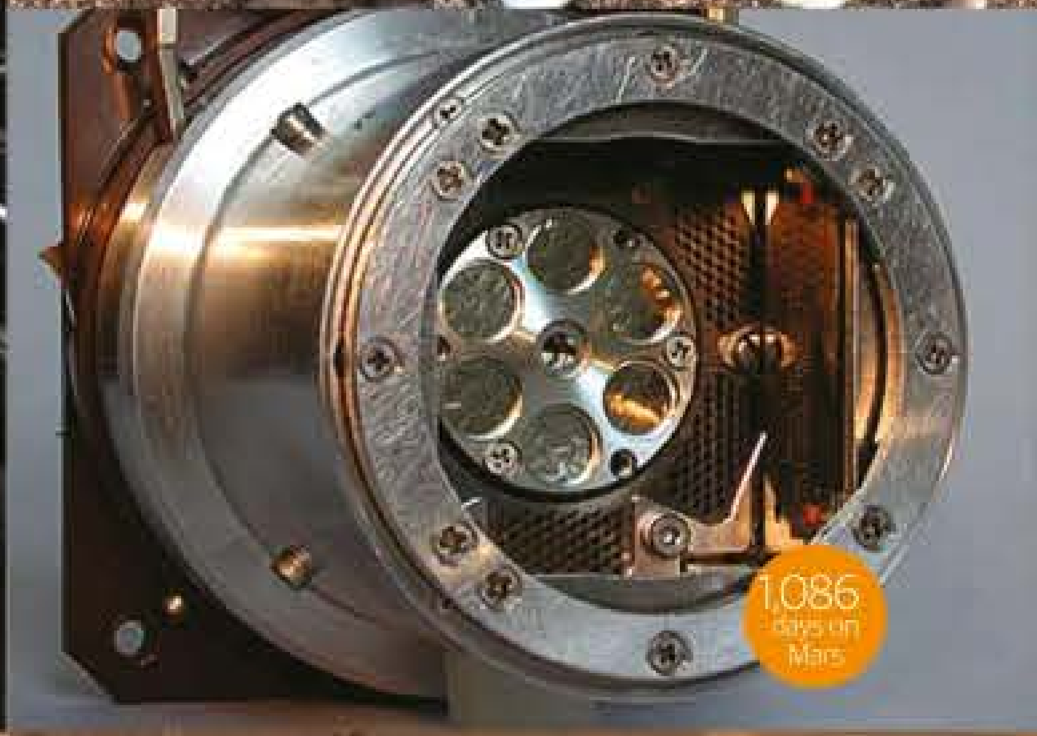
☑ Work out potential for life

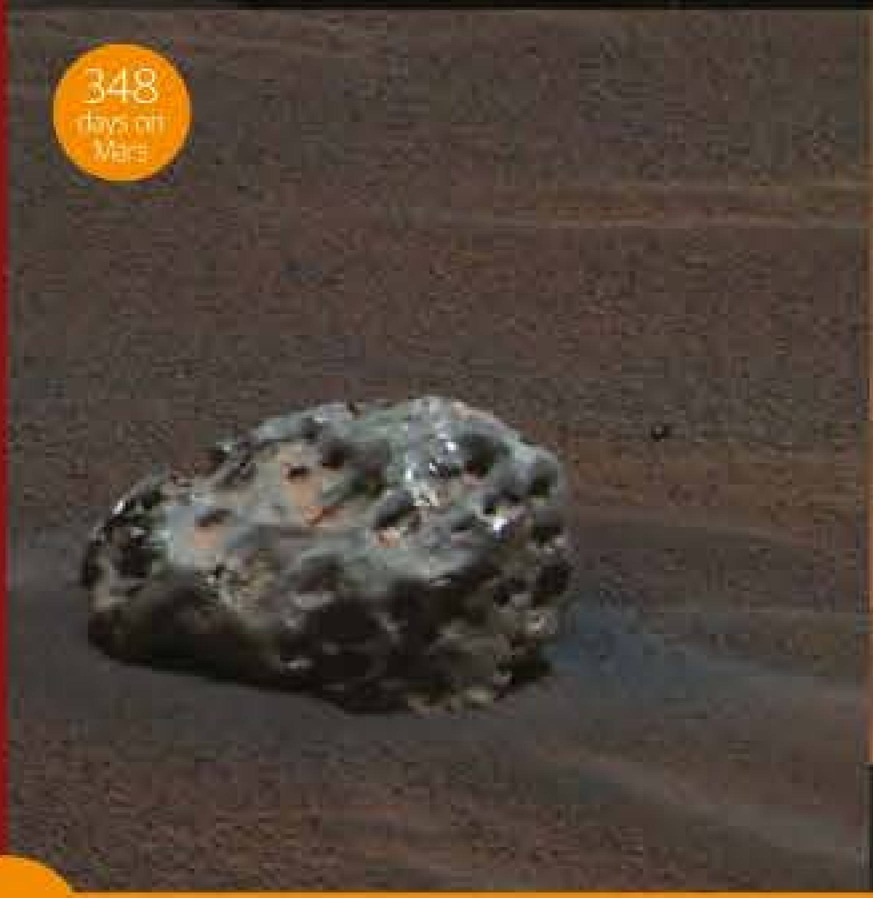
Many of the discoveries by Opportunity pointed towards the likelihood that Mars could have supported life.

Opportunity









25 JANUARY 2004

Days on Mars: 1

Simply landing was a major feat, and the fact Opportunity followed its twin Spirit rover three weeks earlier was really quite remarkable. It touched down on a smooth-flat plain on the opposite side of Mars to Spirit, having approached the surface at more than 19,000 kilometres (12,000 miles) per hour. It was soon sending images back and trundling along the surface.

2 MARCH 2004

Days on Mars: 38

Opportunity's imaging at its landing site in Eagle's rim provided the first close-up view of finely layered sedimentary rocks on Mars, a major breakthrough since it showed liquid water had pooled on the surface at some point. The rocks "clearly preserve a record of environmental conditions different from any on Mars today," Dr Steve Squyres said.

19 APRIL 2004

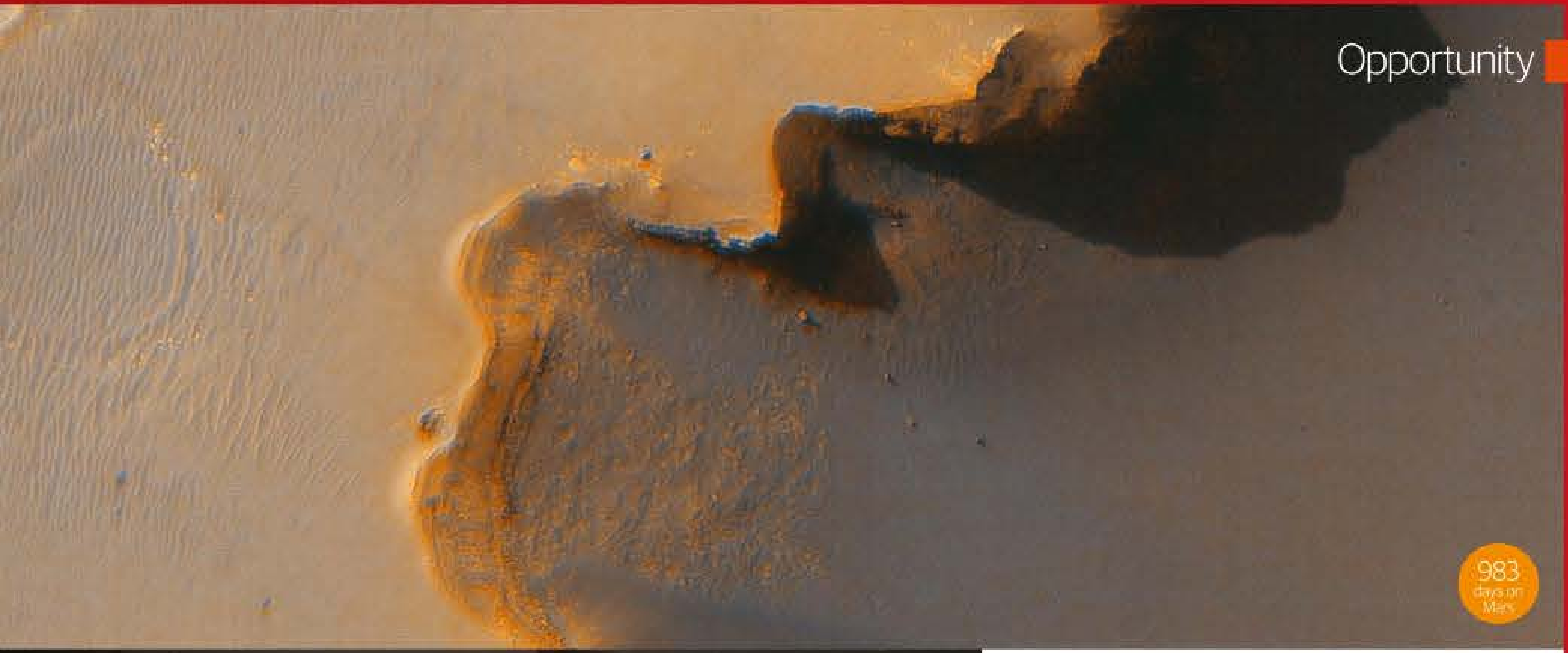
Days on Mars: 86

Groups of grey-blue mineral spheres were examined by Opportunity's composition-reading Mössbauer spectrometer. Scientists found they contained hematite, providing early evidence of a history of water on the Red Planet since it's typically found in places on Earth where standing water or mineral hot springs were once present.

6 JANUARY 2005

Days on Mars: 348

Opportunity discovered a pitted meteorite the size of a basketball in a cratered flatland of Mars called Meridiani Planum and found it was mostly made of iron and nickel. Since it was located close to debris from Opportunity's heat shield it became known as Heat Shield Rock, and it was the first meteorite ever spotted on another planet.



> "I cannot think of a more appropriate place for Opportunity to endure on the surface of Mars than one called Perseverance Valley"
>
> **Michael Watkins, director of JPL**

20 MAY 2005
Days on Mars: 480

A rover's life is never a simple one. Although it set a distance record for one-day travel when it trundled along for 177.5 metres (582 feet) on 19 February 2005, come April it had become stuck in a sand dune, with its wheels buried rim-deep. Following numerous simulations on Earth, drive commands issued to the rover eventually set it free.

3 OCTOBER 2006
Days on Mars: 983

Having already explored layered rocks in cliffs around Victoria Crater, Opportunity began to make its way down a slope to better investigate the textures and compositions of exposed materials. It was risky: there was every chance Opportunity wouldn't make it back out. It re-emerged in August 2008 having successfully studied the stratigraphy inside.

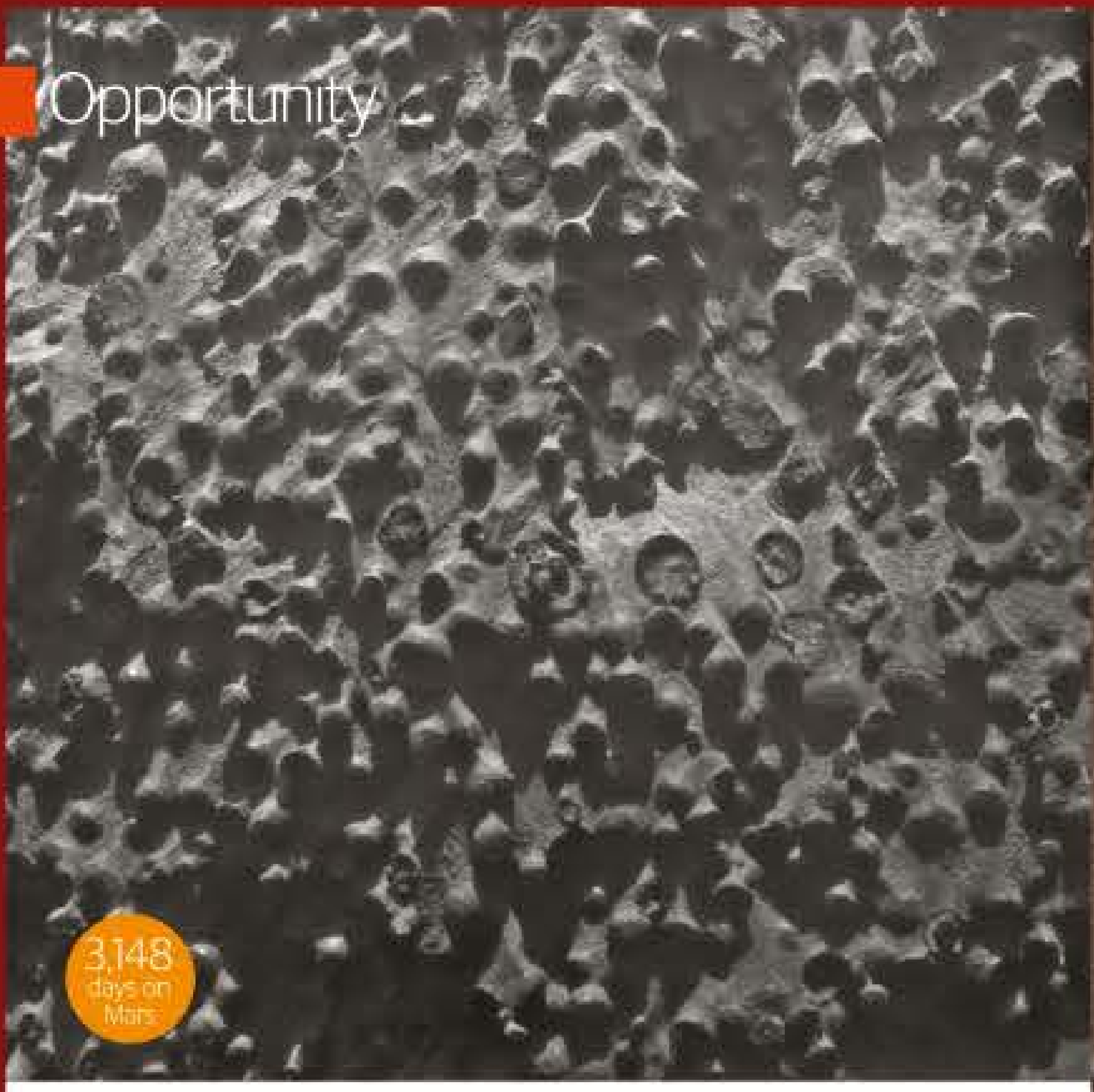
13 JANUARY 2007
Days on Mars: 1,086

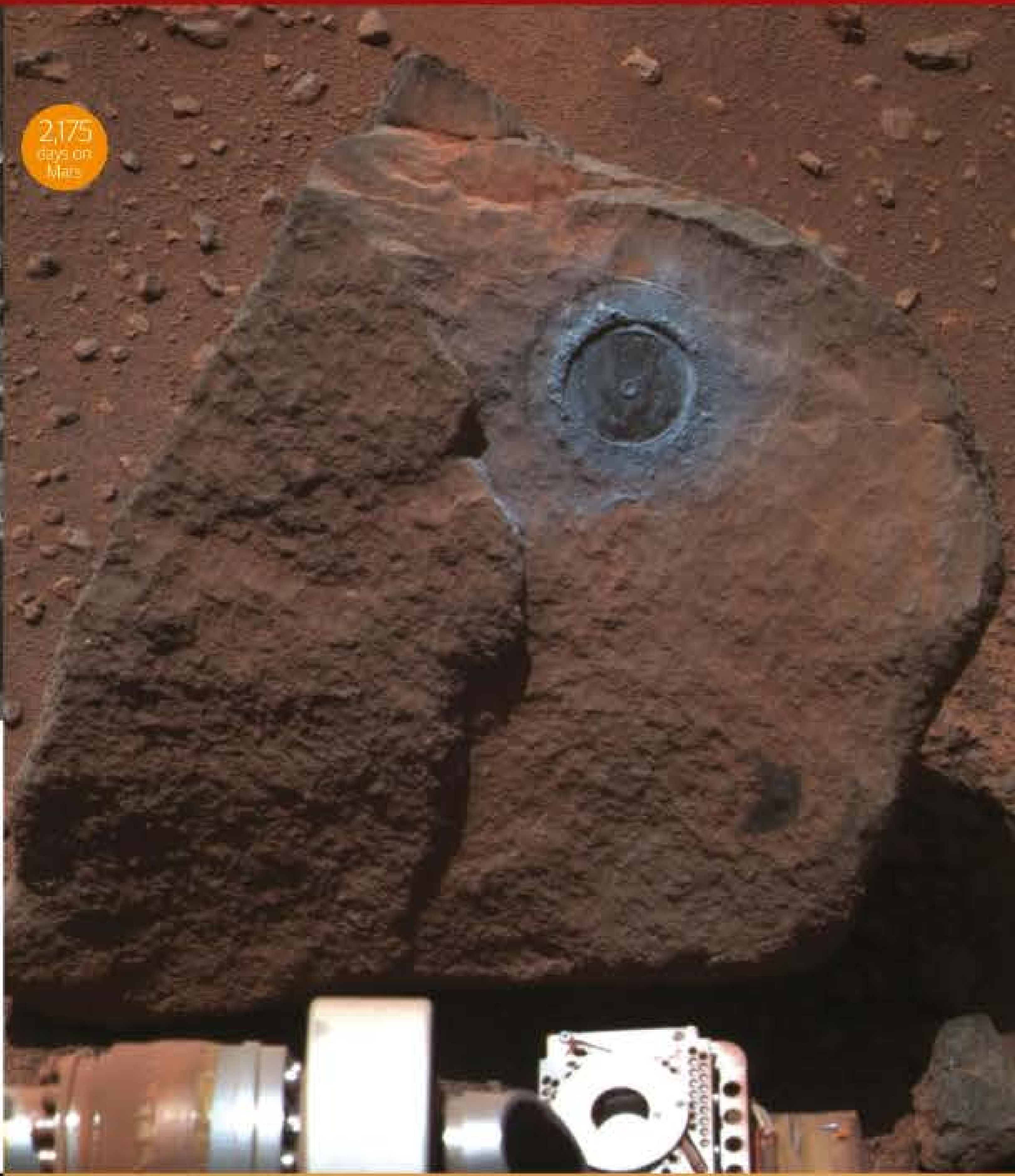
Rather than measuring the chemical content of rocks and dust on the ground, Opportunity began to use its Alpha Particle X-ray Spectrometer to detect the amount of argon in Mars' atmosphere. With Spirit doing the same, the two rovers could determine the atmospheric mixing processes between the polar air and the air at the tropics over time.

17 JULY 2009
Days on Mars: 2,001

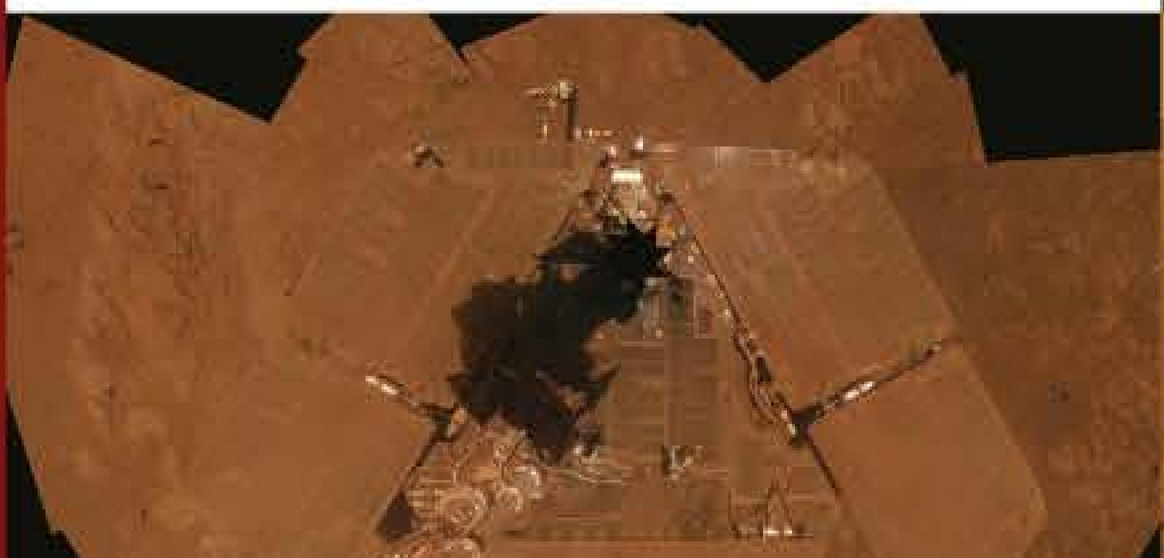
Three iron meteorites were found by Opportunity over a small area on Meridiani Planum: Block Island, Shelter Island and Mackinac Island. The first was found in July and it appears to have smashed into the Red Planet's surface in the Noachian period. Block Island was the size of a small ice chest and is thought to have weighed half a ton.

© NASA/JPL-Caltech





> "It is because of trailblazing missions such as Opportunity that there will come a day when our brave astronauts will walk on the surface of Mars"
>
> **Jim Bridenstine, NASA administrator**



6 JANUARY 2010

Days on Mars: 2,175

A rock named 'Marquette Island' was discovered by Opportunity, and it was particularly intriguing because it was unlike any other rock found on Mars, with a different composition and character to the others. Geologists figured it had originated from within Mars' crust due to its coarse texture, pointing towards a slow cooling time.

15 JULY 2010

Days on Mars: 2,364

Even though the Spirit rover had seen many dust devils, they had eluded Opportunity for more than six years. So when its panoramic camera caught sight of one it made for an interesting observation. Indeed, it was hoped another dust devil could help bring Opportunity back to life by blowing dust from its solar arrays eight years later.

7 NOVEMBER 2011

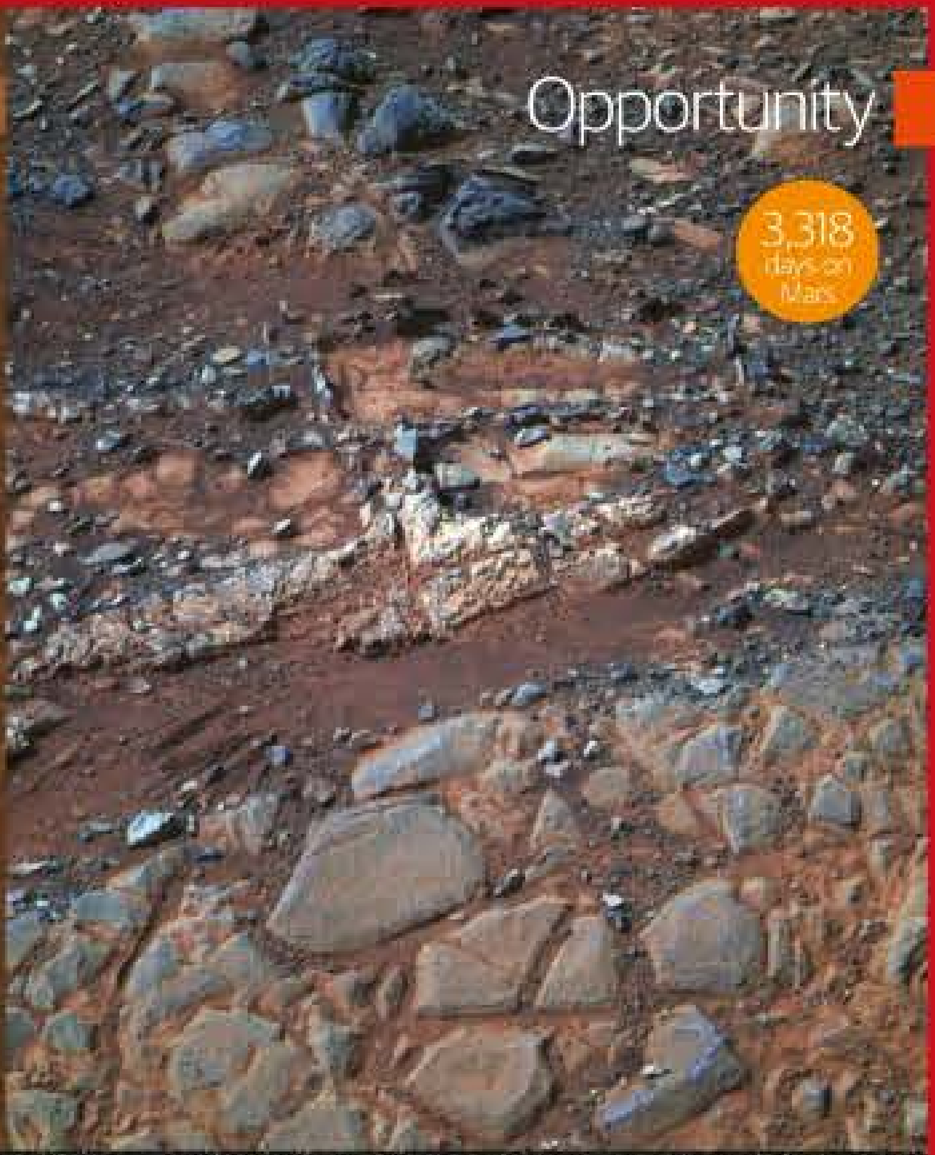
Days on Mars: 2,845

Opportunity had travelled for 32 kilometres (20 miles) before it found bright veins of a mineral called gypsum on a section of Endeavour Crater's rim. They were an indication that water had flowed through underground fractures in rocks. They would have formed when calcium sulphate associated with water.

6 SEPTEMBER 2012

Days on Mars: 3,148

Opportunity took an image of a baffling set of spheres that each measured up to three millimetres across at an outcrop called Kirkwood in the Cape York segment of the western rim of Endeavour Crater. They certainly kept scientists busy, and they were different to the similar-looking spheres found in 2004 since they lacked a high iron content.



23 FEBRUARY 2013

Days on Mars: 3,318

Analyses of ancient clays close to the rim of the Endeavour Crater suggested mild, pH-neutral water had formed between 4.1 and 3.7 billion years ago. Based on the study of a clay mineral called smectite that is rich in aluminium in that location by Opportunity, it pointed towards favourable conditions for ancient microbial life.

22-24 MARCH 2014

Days on Mars: 3,712

There's nothing like a good refresh, and Opportunity certainly benefited when a windswept winter blew its solar panels clean of much debris. Boosted by an increase in solar energy, engineers were able to make use of the power to send it on its way to Murray Ridge on Endeavour Crater. A selfie captured the stark difference the wind made.

7-19 JUNE 2017

Days on Mars: 4,896

In a first for a Martian rover, Opportunity began to drive down a gully carved by a fluid with the aim of getting inside the Endeavour Crater. Scientists wanted to draw comparisons between the rocks found on the plains and in the crater while searching for rocks that predated the crater's formation.

10 JUNE 2018

Days on Mars: 5,251

Opportunity took more than 215,000 images during its time on Mars, but this is perhaps the most poignant because it's the very last one. Snapped as a dust storm blighted the Red Planet for months, the resulting lack of light to its solar panels ensured it never woke from its safe mode. NASA finally decided on 13 February 2019 to give up hope.

© NASA/JPL-Caltech

2019 PREVIEW

FIRST BLACK HOLE IMAGE

In April 2017, a network of telescopes around the world gathered data about the supermassive Sagittarius A* at the centre of the Milky Way - and now it's nearly time to see the very first snap of it

Reported by Lee Cavendish

Black holes are cosmological riddles that scientists have been trying to figure out for a century. The best chance of solving them is with the help of the Event Horizon Telescope (EHT). Before getting into the details of the project, it's important to understand how astronomers and scientists have come up with the idea of black holes without actually seeing one. Black holes are essentially invisible; no light is emitted from them, hence the name. But Albert Einstein and his theory of general relativity, which was first outlined in 1915, states that there are objects large enough that warp time and space to the point where there is a 'point of no return'. At this 'point', or black hole radius, its gravity is so powerful that nothing can escape from within, not even light. This point is known as the event horizon, and this is what a worldwide team of scientists are trying to observe using an array of powerful radio telescopes.

It took over half a century for black holes to become more than just a mathematical anomaly, as the first one was actually discovered in 1971 by

© Nicholas Forder

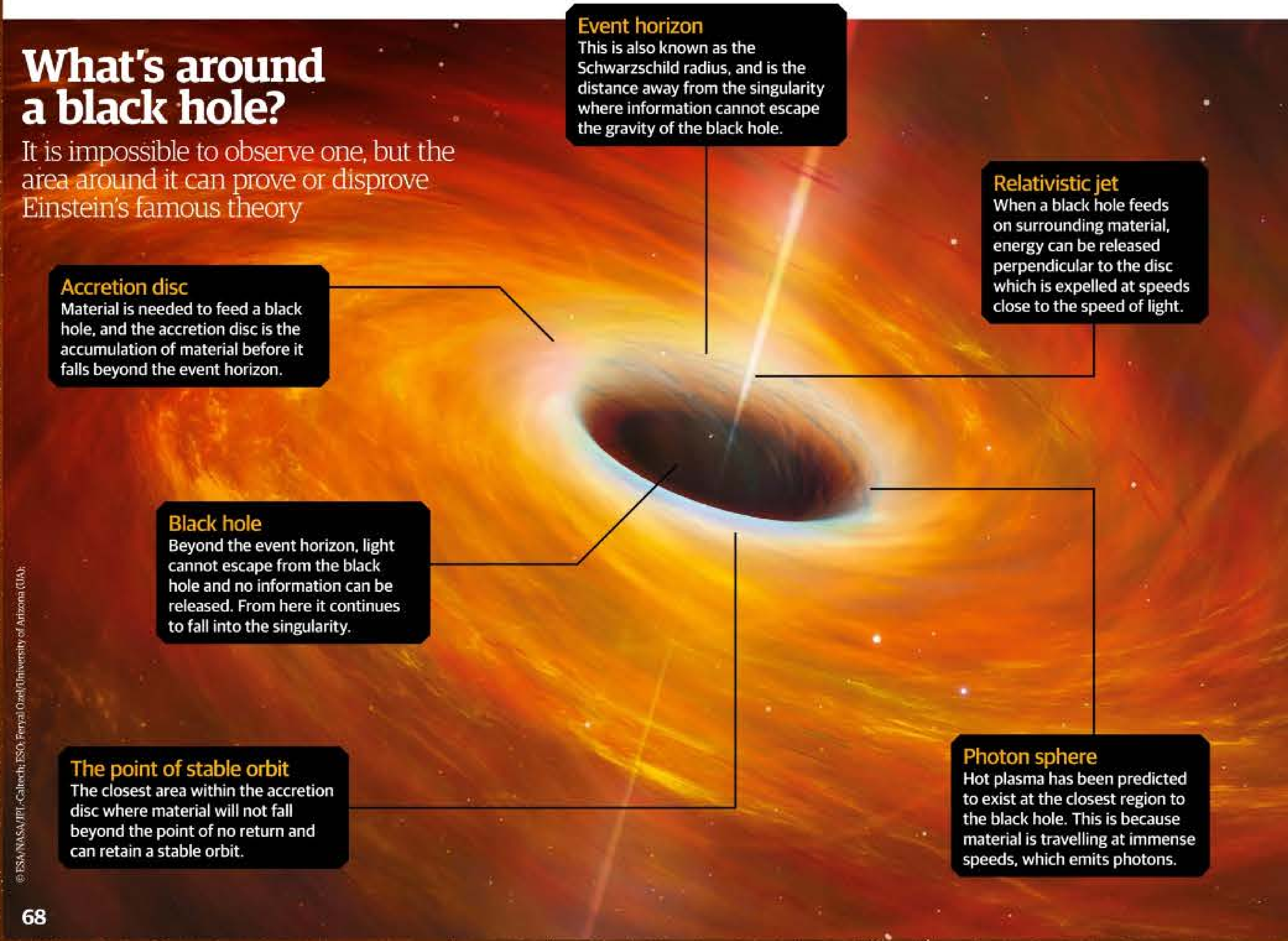
American astronomer John Wheeler. Since then, our knowledge of black holes has come a long way, but not to the extent astronomers wish. For instance, astronomers understand there are different types of black holes: stellar black holes, supermassive black holes and intermediate black holes (IMBHs). Stellar black holes are thought to be scattered all over the universe and move through space. Supermassive black holes are the largest types of black holes and are found at the centre of many galaxies, and IMBHs are thought to be the product of stars colliding in a chain reaction.

The simple way to think about a black hole is that it is an object so dense that its gravity is so powerful, nothing can escape its grasp. But the more complicated answer comes courtesy of Einstein and many other astrophysicists, such as Stephen Hawking. Einstein's theory states black holes create wells in the fabric of space-time, and once anything goes beyond the event horizon the matter is inescapably destined for the point of 'singularity', accommodating an infinite mass. Before matter goes beyond this point, particularly in supermassive black holes, matter can travel at velocities close to the speed of light. These regions create extremely energetic emissions, which can even be seen using radio and X-rays, and are the areas where scientists are looking to understand how Einstein's theory of general relativity and quantum mechanics - the behaviour of particles at high speeds - intertwine. Only by homing in on these regions can scientists look to find the missing link is between the two theories that explain the true nature of the universe. "There's this mathematical construct that we call a 'black hole'. It is something you can derive from the mathematics of Einstein's theory of general relativity. It is the simplest possible astrophysical object because when everything gets 'eaten' by a black hole, when it goes past the event horizon, all the information

> "When it goes past the event horizon, all the information about what went in is practically lost" **Dimitrios Psaltis**

What's around a black hole?

It is impossible to observe one, but the area around it can prove or disprove Einstein's famous theory



Event horizon
This is also known as the Schwarzschild radius, and is the distance away from the singularity where information cannot escape the gravity of the black hole.

Relativistic jet
When a black hole feeds on surrounding material, energy can be released perpendicular to the disc which is expelled at speeds close to the speed of light.

Accretion disc
Material is needed to feed a black hole, and the accretion disc is the accumulation of material before it falls beyond the event horizon.

Black hole
Beyond the event horizon, light cannot escape from the black hole and no information can be released. From here it continues to fall into the singularity.

The point of stable orbit
The closest area within the accretion disc where material will not fall beyond the point of no return and can retain a stable orbit.

Photon sphere
Hot plasma has been predicted to exist at the closest region to the black hole. This is because material is travelling at immense speeds, which emits photons.

© ESA/NASA/JPL-Caltech; ESO; Feryal Ozel/University of Arizona (UA);

about what went in is practically lost," explains Dimitrios Psaltis, a professor of astronomy and physics at the University of Arizona Department of Astronomy and Steward Observatory, United States, and also project scientist of the EHT. "We have only circumstantial evidence that these exist. For example, in the centre of galaxies we can infer that there is this extremely massive object - a billion-times the mass of our Sun - just by how the orbits of all the other stars around them work. On the other hand, Einstein derived his theory of general relativity to explain things that happen in our Solar System. When we apply the theory to the universe as a whole, things don't appear as promising.

"So we're [EHT team] going to a place [in the universe] that makes a very strong prediction of a black hole. We can go to the event horizon, which is the very last place [that astronomers can observe] to see whether the theory's predictions agree with the data."

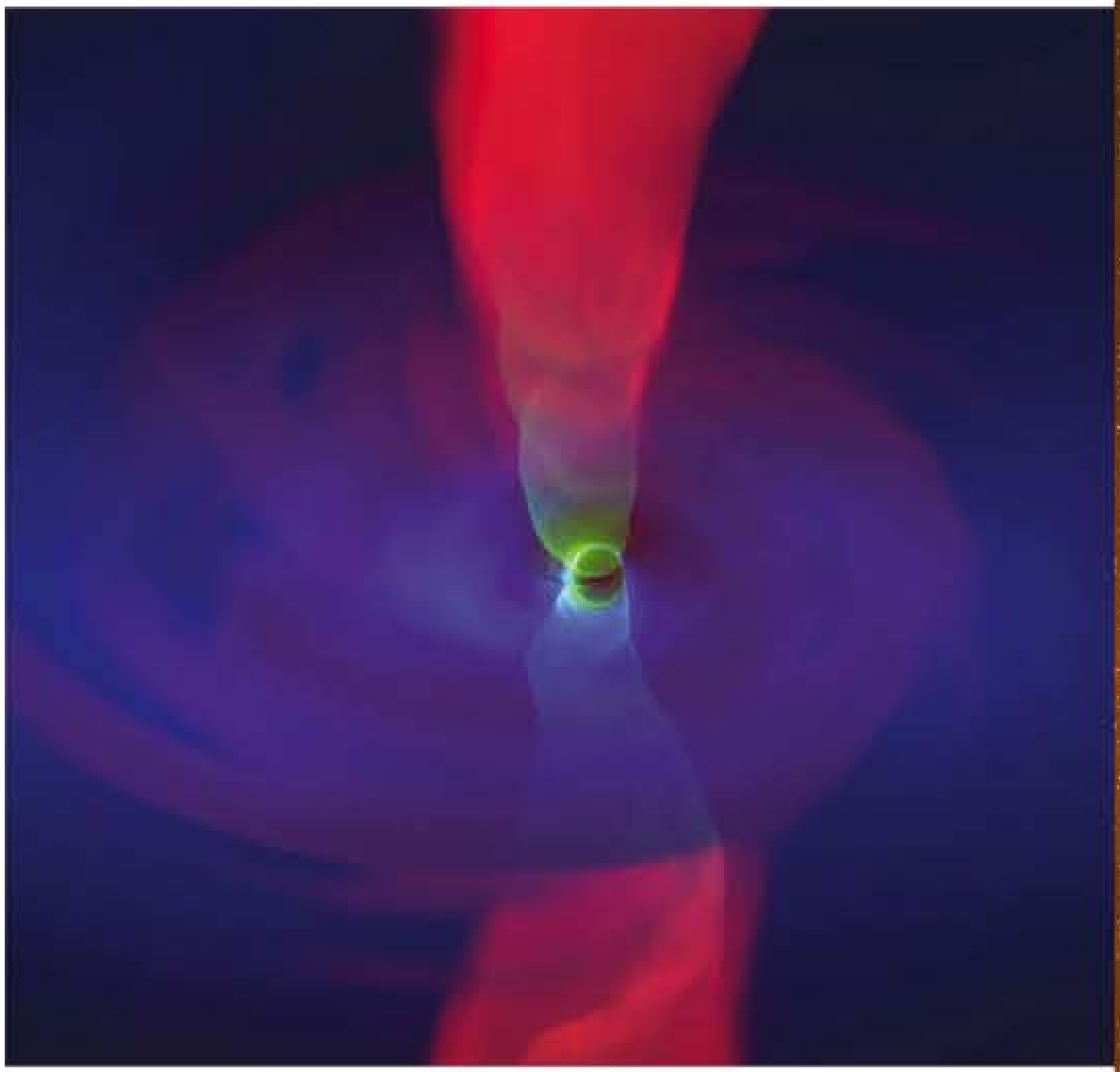
The task of imaging a black hole is difficult, and has only been given a glimmer of hope in modern times thanks to the evolution of technology and the increased development of large telescopes. In order to accomplish such a feat, astronomers are teaming up to try and image the supermassive black hole residing at the centre of the Milky Way, Sagittarius A* (Sgr A*). To put this task into a distance-related context, it would be the same as being in New York and trying to count the dimples on a golf ball in Los Angeles, California.

"One of the main things you need to understand about the EHT is that in order to increase the resolution, or crispness, of a picture, you need to increase the size of your telescope. The bigger the telescope, the crisper you can see things. The question is, then, how big must the telescope be in order to take a picture of the black hole at the centre of our galaxy, for example, in millimetre wavelengths? It turns out to be the size of the Earth," says Psaltis.

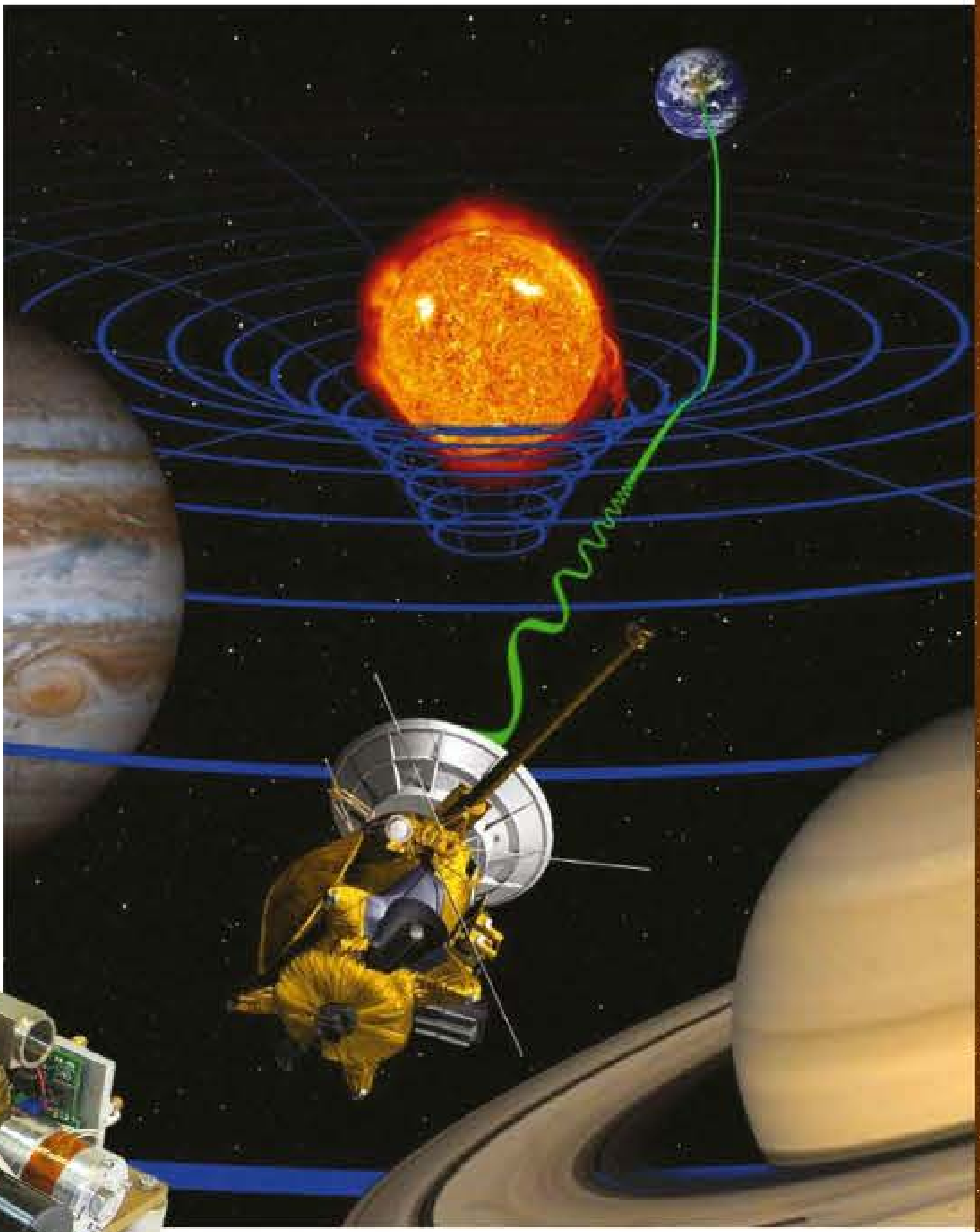
What Psaltis and his team can do is create a network of telescopes and take a number of pictures at the same time and superimpose them, creating an artificial Earth-sized telescope. This is a technique known as Very Long Baseline Interferometry (VLBI), and EHT officially began the collaboration in 2012 after a conference held by the University Of Arizona, which included teaming up with the Global mm-VLBI Array (GMVA) project. This introduced many telescopes with millimetre wavelength observations such as the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile, Radio Telescope Effelsberg in Germany, Yebes Observatory in Spain, the Green Bank Telescope in West Virginia and the The Very Long Baseline Array (VLBA) in New Mexico. This makes a formidable team with the EHT's South Pole Telescope in Antarctica, the Atacama Pathfinder Experiment in Chile, the Large Millimeter Telescope in Mexico, the Northern Extended Millimeter Array in France, the IRAM telescope in Spain, the Submillimeter Telescope in Arizona and the James Clerk Maxwell Telescope and Submillimeter Array in Hawaii.

Top left: There is a lot of gas and dust between Earth and the galactic centre to pierce through

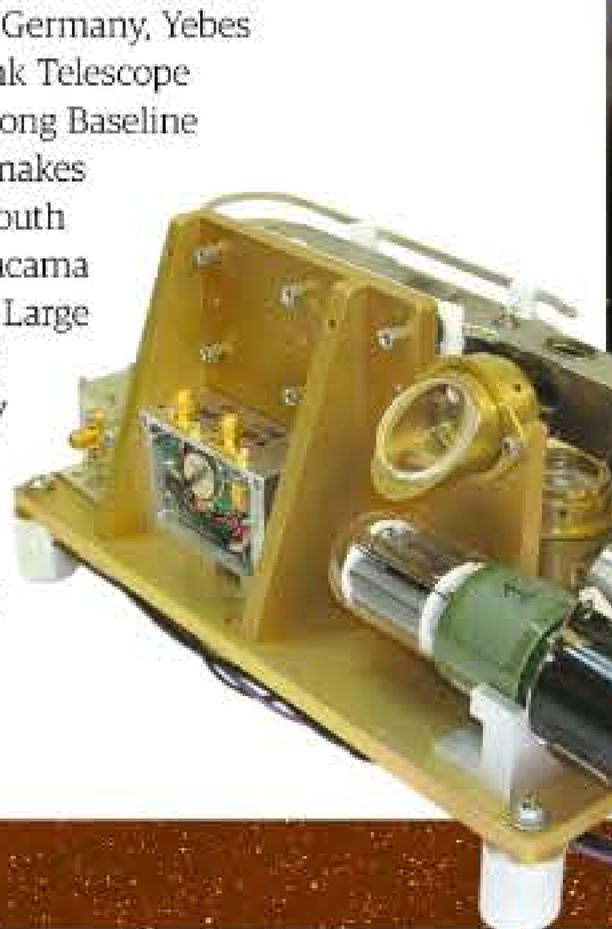
Left: Supermassive black holes are thought to exist at the centre of each galaxy



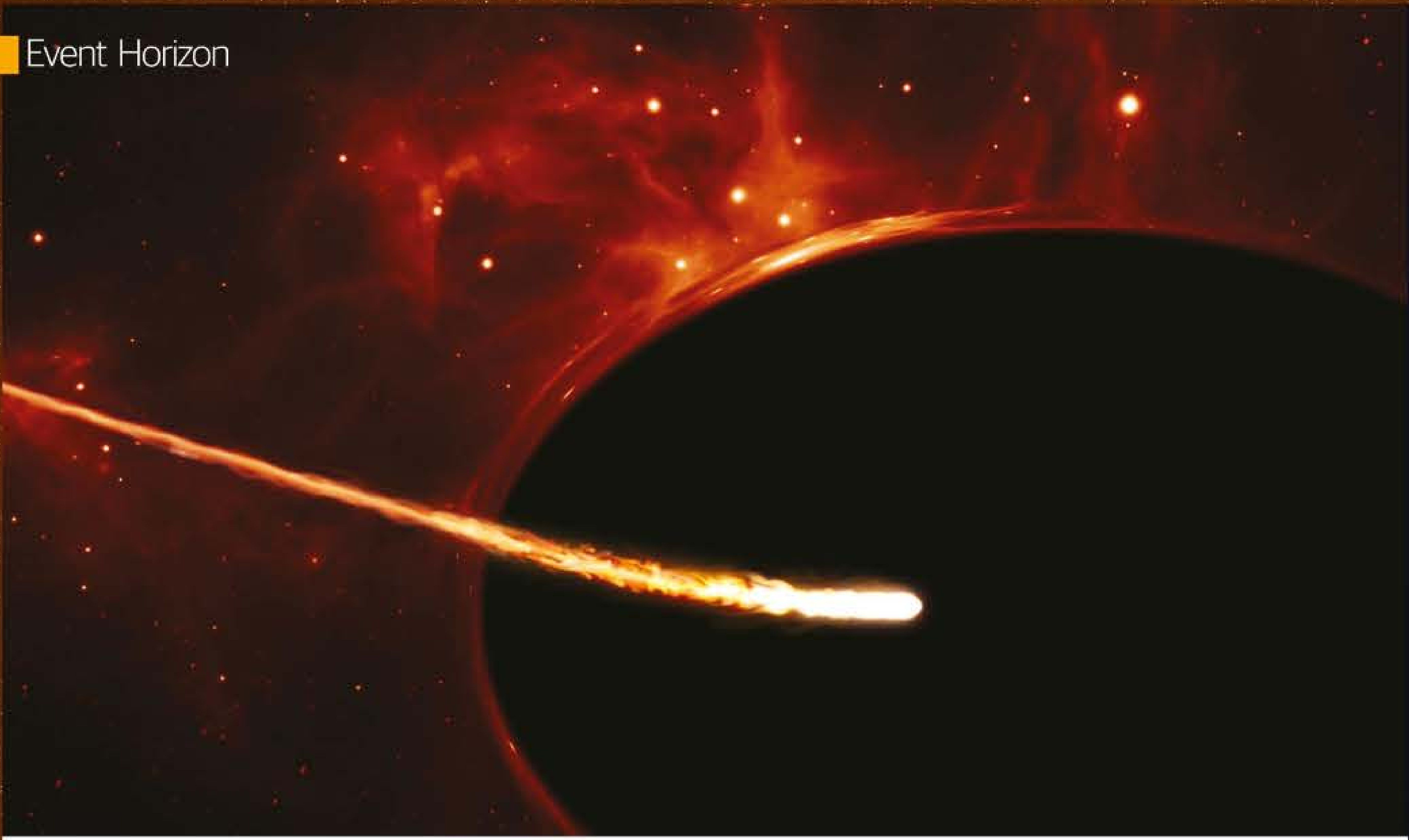
Right: This is a real simulation image of what a black hole should look like



Bottom right: Einstein's theory of general relativity has been tested within our Solar System, but never at this scale with a black hole



Bottom: Atomic clocks are used in astronomy to measure time incredibly accurately



Even at distances such as this the finite speed of light would cause a delay in communication between each other. This would lead to data being collected at different times and would not bring the black hole into focus, as the astronomers would like. So how do over ten telescopes make an observation at the exact same time? The answer: atomic clocks. "You need not only measure the light at a very high pace, but you also need to time target. You need to be able to tell at what time every measurement happened, so when you put the data into a supercomputer you can line up the times. The data collection needs to be timed at an incredibly high accuracy, which is why we're using atomic clocks," says Psaltis. "Every telescope has its own atomic clock that effectively times to within one part in ten billionth of a second." This is a level of accuracy down to the nanosecond.

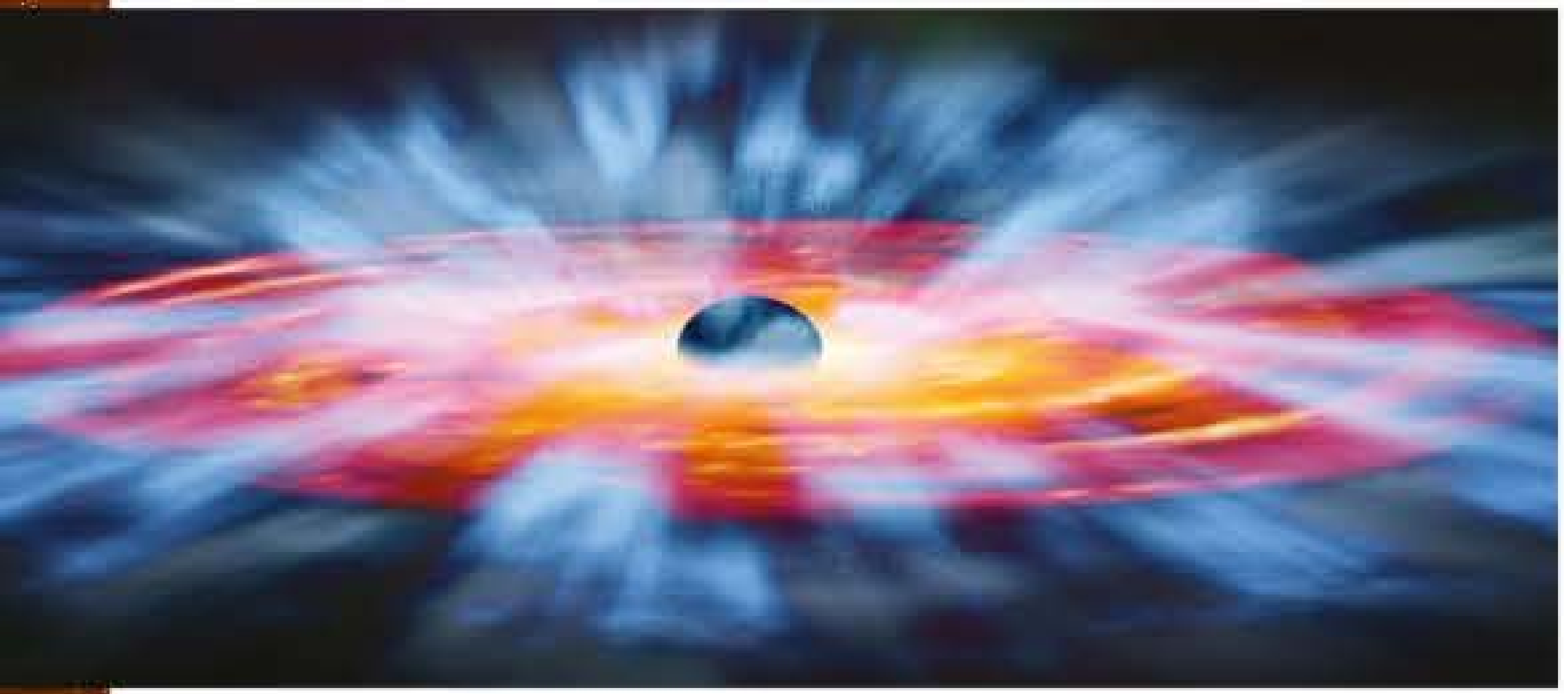
In April 2017 the EHT project made a week-long observation that linked together various telescopes. This was a historic week that not only targeted Sgr A*, but also a black hole at the heart of M87, an elliptical galaxy about 50 million light years away. The week was a culmination of years of hard work by a worldwide team of astronomers, but this wasn't the end. All of the data had to be processed with maximum diligence, which has taken an extremely long time. Particularly data from the South Pole, as it wasn't able to be sent digitally. Instead it had to be made into hard copies and then sent via a courier service - which surprisingly enough, doesn't visit the South Pole often - and sent to its destination. Simply delivering the data from the telescope took a matter of months.

"The black hole is in the middle, effectively eating all the light" **Dimitrios Psaltis**

While the data is being processed, astronomers have also been completing simulations to determine what a black hole may look like. "The main thing you see [in simulations] is a lot of plasma that is very hot outside the black hole and emits a lot of radiation," Psaltis describes. "But the black hole is in the middle, effectively eating all the light that goes near it, and it leaves a silhouette. All our simulations show that you see things all around with a hole in the middle of the emission."

The majority of people may switch their focus immediately to 'Gargantua'; the black hole depicted in the 2014 film *Interstellar*. In terms of scientific accuracy, it is close. In fact, the movie had Nobel prize-winning astrophysicist Kip Thorne helping create simulations that showed the production team what Gargantua would look like. But production decided that it wasn't 'sexy' enough, so ignored some of the science. But these hydrodynamic simulations are extremely complicated, as Psaltis tells us: "There's a lot of turbulence, a lot of magnetic fields; there's just a lot of things that are happening. We have observations at different wavelengths that allow us to constrain a lot about what our predictions are. It involves using our best understanding of physics and then making predictions as to what a black hole will look like."

The best is yet to come, though. The aforementioned mountain of data that came from the black-hole-hunting week in April 2017 has needed the help of many institutions with the unappreciated groundwork in processing and analysing the data, making sure it goes through the correct peer-review process. The end is near, though, and soon the public may be staring at an image of the region around the mysterious doyen of our Milky Way, Sgr A*, within a matter of months, instead of a matter of years.

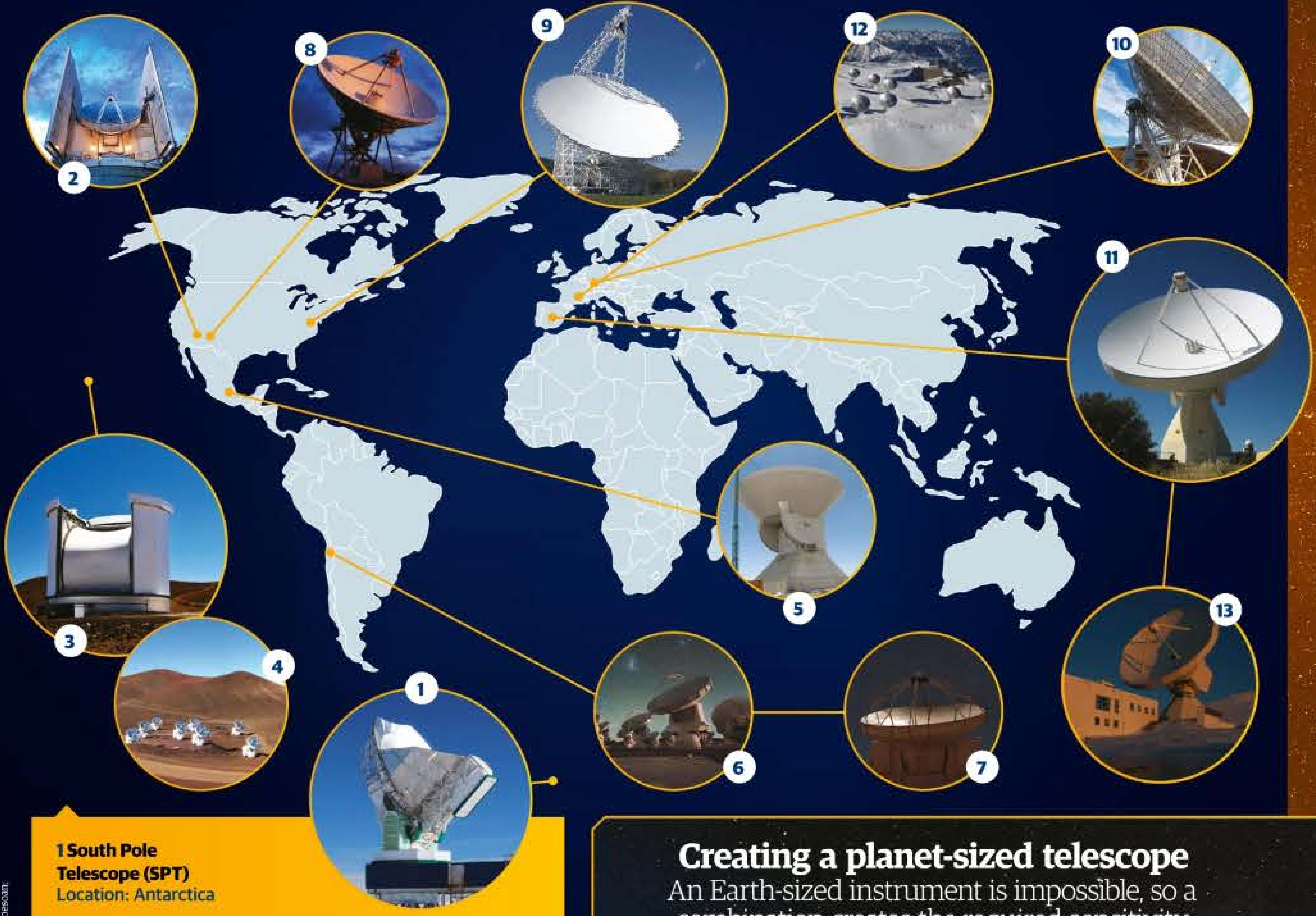


Above: A star approaching a black hole will essentially disappear when passing the event horizon

Left: Black holes have been depicted for decades, but have never been observed

The network that will image a black hole

These global telescopes will blaze a trail for black hole imaging and revolutionise astrophysics



1 South Pole Telescope (SPT)
Location: Antarctica

2 Arizona Radio Observatory/Submillimeter Telescope (ARO/SMT)
Location: United States

3 James Clerk Maxwell Telescope (JCMT)
Location: Hawaii

4 Submillimeter Array
Location: Hawaii

5 Large Millimeter Telescope (LMT)
Location: Mexico

6 Atacama Large Millimeter/submillimeter Array (ALMA)
Location: Chile

7 Atacama Pathfinder Experiment (APEX)
Location: Chile

8 Very Long Baseline Array (VLBA)
Location: United States

9 Robert C. Byrd Green Bank Telescope (GBT)
Location: United States

10 Radio Telescope Effelsberg (MPIfR)
Location: Germany

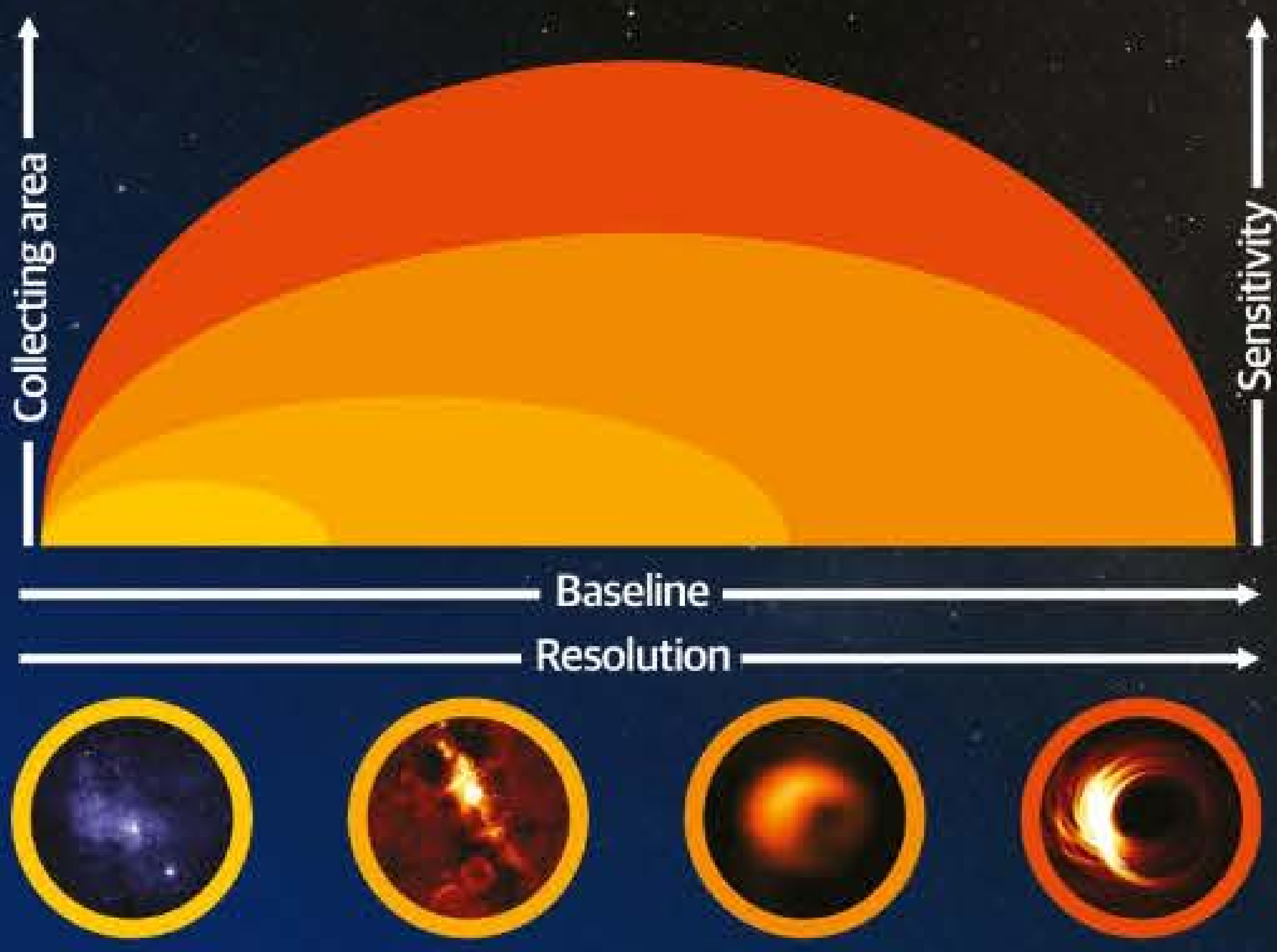
11 Yebes Observatory
Location: Spain

12 Northern Extended Millimeter Array (NOEMA)
Location: France

13 Institut de Radioastronomie Millimétrique (IRAM)
Location: Spain

Creating a planet-sized telescope

An Earth-sized instrument is impossible, so a combination creates the required sensitivity



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Did you know?

The European Space Agency (ESA) was formed in May 1975 and is comprised of 22 member states. Its headquarters is located in Paris, the capital of France

SPACE EXPLORATION

Will ESA astronauts ever explore beyond low-Earth orbit?

Yes, it has been an ambition for a long time to be involved in deep-space exploration. There are [ESA] studies going back ten years on lunar exploration and of where we go next, so it is very much the long-term ambition of ESA to have astronauts heading out beyond low-Earth orbit. Of course we still need to stay in low-Earth orbit to do the science and research that happens there. But increasingly that may move to a more commercialised model. We're already seeing commercial companies [in the US] involved in taking cargo and, eventually, crewed vehicles to the International Space Station (ISS). But the vision is to go further, definitely.

As far as the agreement goes today, the first crewed mission will involve NASA astronauts – we are building something and they will get to fly it. But eventually one day the ISS will come to an end, and the sort of ideas being talked about are concepts of a deep-space habitat – the idea that we have a crewed vehicle in orbit that is able to carry four people with at least a laboratory and an electric propulsion system to be in orbit and do shakedown cruises in deep space.

Dr David Parker is the European Space Agency's director of human spaceflight and robotic exploration

Above: Tim Peake is one of the few ESA astronauts to visit the ISS

ASTROPHYSICS

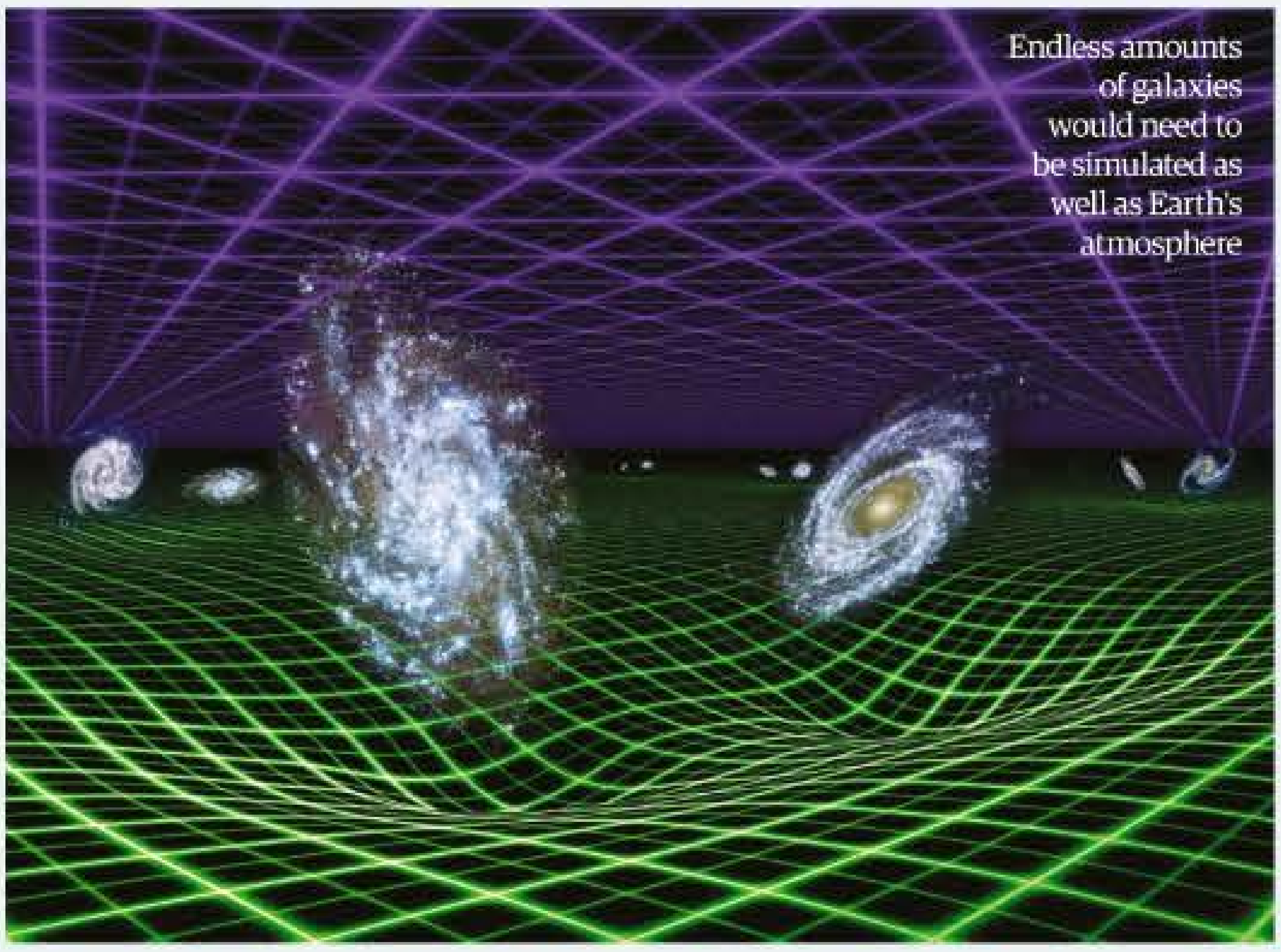
Could we be living in a simulation?

There are several interpretations of that. Some people think that reality may be a simulation, like in *The Matrix*. I don't think so. First of all, using Newton's laws and assuming that the atmosphere is composed of tiny little marbles instead of atoms, the world's largest computer could not simulate the atmosphere. It's too complicated. The smallest object that can simulate the weather is the weather itself. Weather is therefore 'unsimulatable' as it has too many particles.

Quantum mechanics makes it incidentally worse, because now instead we have billiard balls representing atoms. Atoms can also spin up, spin down and spin sidewards simultaneously. It becomes a nightmare trying to simulate quantum mechanics and the motion of particles.

Therefore I do not believe that we are in a simulation. I don't think there is a super CD-ROM where if you push the play button then here we are having this conversation. I think quantum mechanics is simply too complex, with too many possibilities, so that reality can be reduced to a CD-ROM and somebody hitting our play button.

Michio Kaku is a popular science communicator and professor of theoretical physics at the City College of New York



Endless amounts of galaxies would need to be simulated as well as Earth's atmosphere

> "The world's largest computer could not simulate the atmosphere. It's too complicated" **Michio Kaku**

There are a large number of near-Earth objects that could cause harm to our planet

SOLAR SYSTEM

Do you think we should spend more on 'safeguarding' Earth from asteroid impacts?

Well of course, those risks are among the few that we can quantify. We know how probable impacts by rocks of different sizes are, and the biggest threat is from the rare big ones. I think if you do a normal calculation working out the probability and the consequences and what insurance premium you should spend to reduce that risk, you come up with a number like £100 million or £200 million a year. That's the kind of premium that would be worth spending to reduce the risk of an asteroid impact.

It is good that there is talk about doing this and spending money in two different ways. One way is to do a more complete survey so that we can monitor the orbits of all the asteroids down to about 15-metres (49-feet) across, not just the very big ones, and so be alert to any that might be in orbits that could crash into the Earth. The other is to think a bit more about the technology to deflect them if they do get too close. So I think it's worth some effort, but that risk doesn't keep me awake at night.

Lord Martin Rees is a British cosmologist and Astronomer Royal

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ASK Space

Our experts answer your questions

ASTROPHYSICS

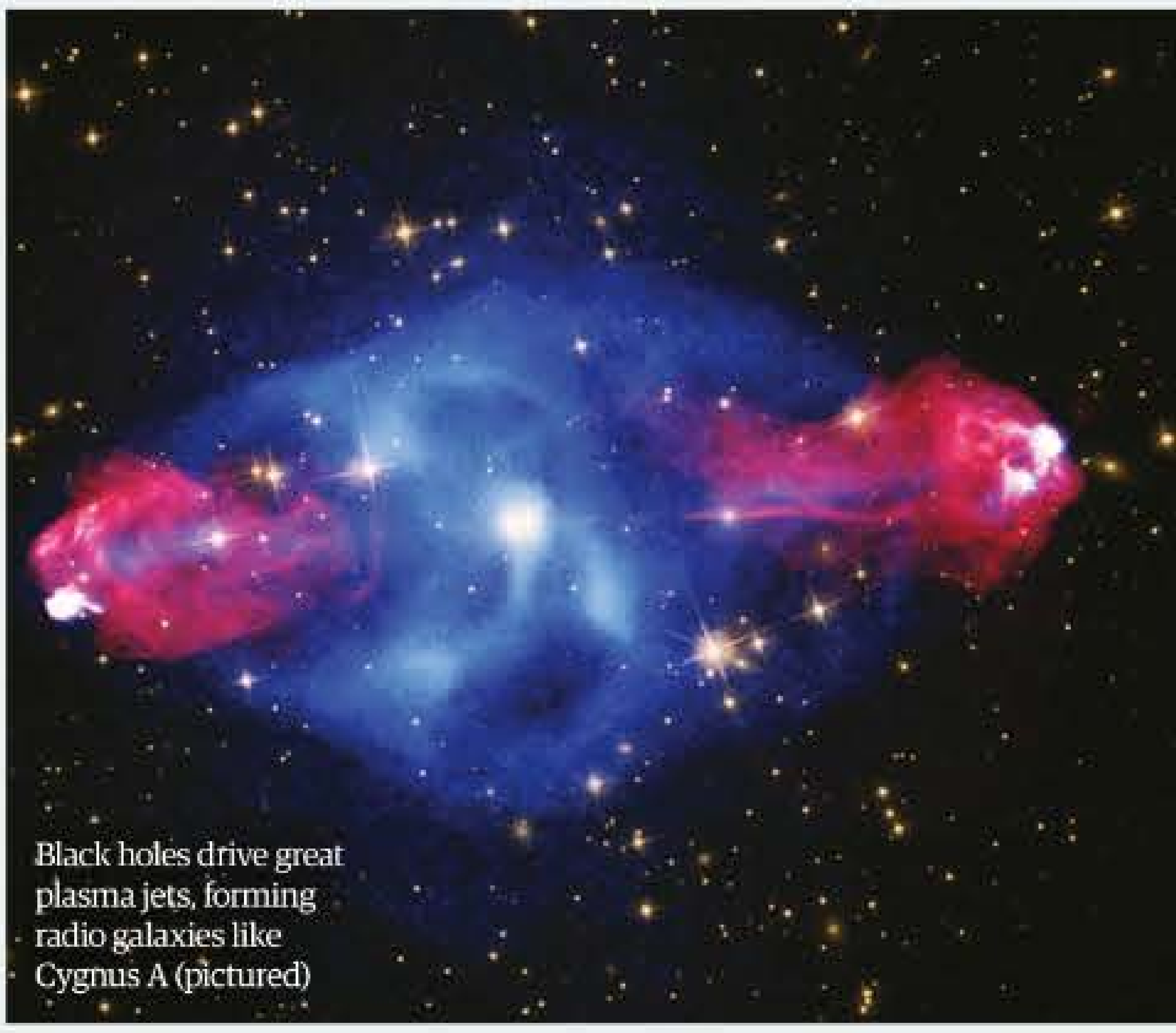
Can anything escape a black hole?

No particle - not even a photon moving at the speed of light - can move outward through a black hole's horizon, which acts like a one-way surface of no return. However, energy can 'escape' the horizon.

If a spinning black hole is threaded by a magnetic field the rotation of space-time can wind the magnetic field into a rotating helix, which carries energy away from the hole. This is believed to be how black holes drive powerful relativistic jets of plasma, forming spectacular radio galaxies like Cygnus A. Another way the energy stored in a black hole's rotation can be extracted is by using particles which appear to have negative energy - a strange state which can only occur very near a spinning hole when particles try to move against the rotation of space-time.

When these negative-energy particles go inward through the horizon it's equivalent to positive energy moving outward, so again the rotational energy of the black hole decreases. The astrophysical consequences of this process are less clear, but recent numerical simulations suggest that these negative-energy particles may in some cases be numerous enough to compete with energy extraction by magnetic fields.

Kyle Parfrey is a senior NASA postdoctoral fellow at Goddard Space Flight Center, Greenbelt, Maryland



Black holes drive great plasma jets, forming radio galaxies like Cygnus A (pictured)

Titan is the largest moon of Saturn and also the second largest in the Solar System

© NASA, JPL, Kevin McGivern

MOONS

How did Titan develop such a thick atmosphere?

Nitrogen in Titan's atmosphere may have come from the conversion of ammonia ice plus gases produced by heating large organic molecules in the moon's interior. Both compounds are found in comets, which are records of the building blocks of the outer Solar System. Gases produced via heating in Titan's interior may have been released by cryovolcanism or large-scale overturn processes. The release of gas from planetary interiors is called outgassing and was an important process in the formation of Earth's atmosphere. Measurements at Titan of argon-40, which is a radioactive daughter product of potassium-40, suggest that outgassing occurred at Titan as well. Potassium is present in Titan's rocky interior rather than its icy surface, meaning argon-40 originated in side the Saturnian moon.

In addition to nitrogen, Titan's atmosphere has approximately five per cent methane, critical to atmospheric stability. As a greenhouse gas, methane keeps Titan's atmospheric temperature high enough to prevent the nitrogen from freezing. Chemical reactions driven by ultraviolet light from the Sun consume methane, causing it to produce larger organic molecules. At current rates, this process may destroy all of Titan's methane in a time frame less than one per cent of the age of the Solar System, meaning that it is possible that Titan has not always had an atmosphere. However, another possibility is that Titan's atmospheric methane is replenished by outgassing or from a currently unknown methane reservoir within the moon's crust.

Dr Kelly Miller is a cosmochemist research scientist at the Southwest Research Institute in San Antonio, Texas

> "Methane keeps Titan's atmospheric temperature high enough to prevent the nitrogen from freezing" **Dr Kelly Miller**

ASTROCHEMISTRY

How much alcohol is in space?

There is a great deal of alcohol in space, and I mean that not just by volume but also by variety. There are vast oceans upon oceans worth of ethanol, or ethyl alcohol, the kind we might drink in beer or wine or cocktails, floating in great interstellar clouds; the birthplaces of stars and planets. But there is also a wide variety of other molecules that we chemists classify as alcohols. The most abundant and widespread of these is methanol, or methyl alcohol, and is actually chemically simpler than 'drinking alcohol'.

On Earth it is most commonly known as a toxic by-product of home-distilling operations. In space it is one of the most common organic molecules and is the feedstock for a multitude of reactions that lead to far more complex chemistry occurring in the universe. Some of these more complicated alcohols, like methoxymethanol, have been found by researchers in recent years. Others, like propanol – just one step more complex than ethanol – is suspected to be out there but is yet to be found!

Brett McGuire is a Hubble Fellow of the National Radio Astronomy Observatory at the Harvard-Smithsonian Center for Astrophysics

Below: With the amount of alcohol in space, astronauts could have a great time!

Did you know?

Anheuser-Busch, the parent company of Budweiser, has stated it would like to make beer on Mars, even sending barley to the ISS for tests.

ASTROPHYSICS

How can you find out the age of a star?

The trick is to use well-tested theories of fusion and energy transport and the known properties of matter, which tell us that a star changes its surface temperature and brightness in a predictable manner over time.

The Sun, for example, will double in brightness over the next 6 billion years until it consumes its supply of hydrogen, after which it will brighten by a factor of 1,000 and become a red giant. About 7 billion years from now it will expel its outer layers, leaving behind a core which we call a white dwarf. Most stars do this, though at different ages depending on their mass. If we can work out a star's 'heaviness', surface temperature and brightness, we can figure out how old a stellar object is.

This approach is most sensitive when the star's properties change the most rapidly, which happens right after it finishes consuming hydrogen in its core and again when a star is a white dwarf. Gaia, an ESA satellite [mapping the Milky Way], is helping us to measure stellar properties with unprecedented precision, which in turn is allowing us to determine the ages for millions of stars.

Ted von Hippel is director of the Physical Sciences Department Observatory at Embry-Riddle Aeronautical University

STARGAZER

ESSENTIAL GUIDES AND ADVICE FOR AMATEUR ASTRONOMERS

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What's in the sky?

Red light friendly
In order to preserve your night vision, you should read our observing guide under red light

29 MAR
Conjunction between the Moon and Saturn in Sagittarius

29 MAR
The Moon and Saturn make a close approach, passing within 0°03' of each other in Sagittarius

29 MAR
The Moon and Pluto make a close approach, passing within 0°18' of each other in Sagittarius

5 APR
Spiral galaxy Messier 94 is well placed for observation in Canes Venatici

5 APR
Asteroid 7 Iris is well placed for observation in Corvus

6 APR
Asteroid 2 Pallas is well placed for observation in Boötes

12 APR
The Virginids reach their peak of five meteors per hour

13 APR
Mercury reaches half phase (dichotomy), shining brightly at magnitude 0.2

13 APR
The Moon and Messier 44 make a close approach within 0°04' of each other in Cancer

Naked eye
Binoculars
Small telescope
Medium telescope
Large telescope

17 APR
The Southern Pinwheel Galaxy (M83) is well placed for observation in Hydra

18 APR
Globular Cluster M3 is well placed for observation in Canes Venatici

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

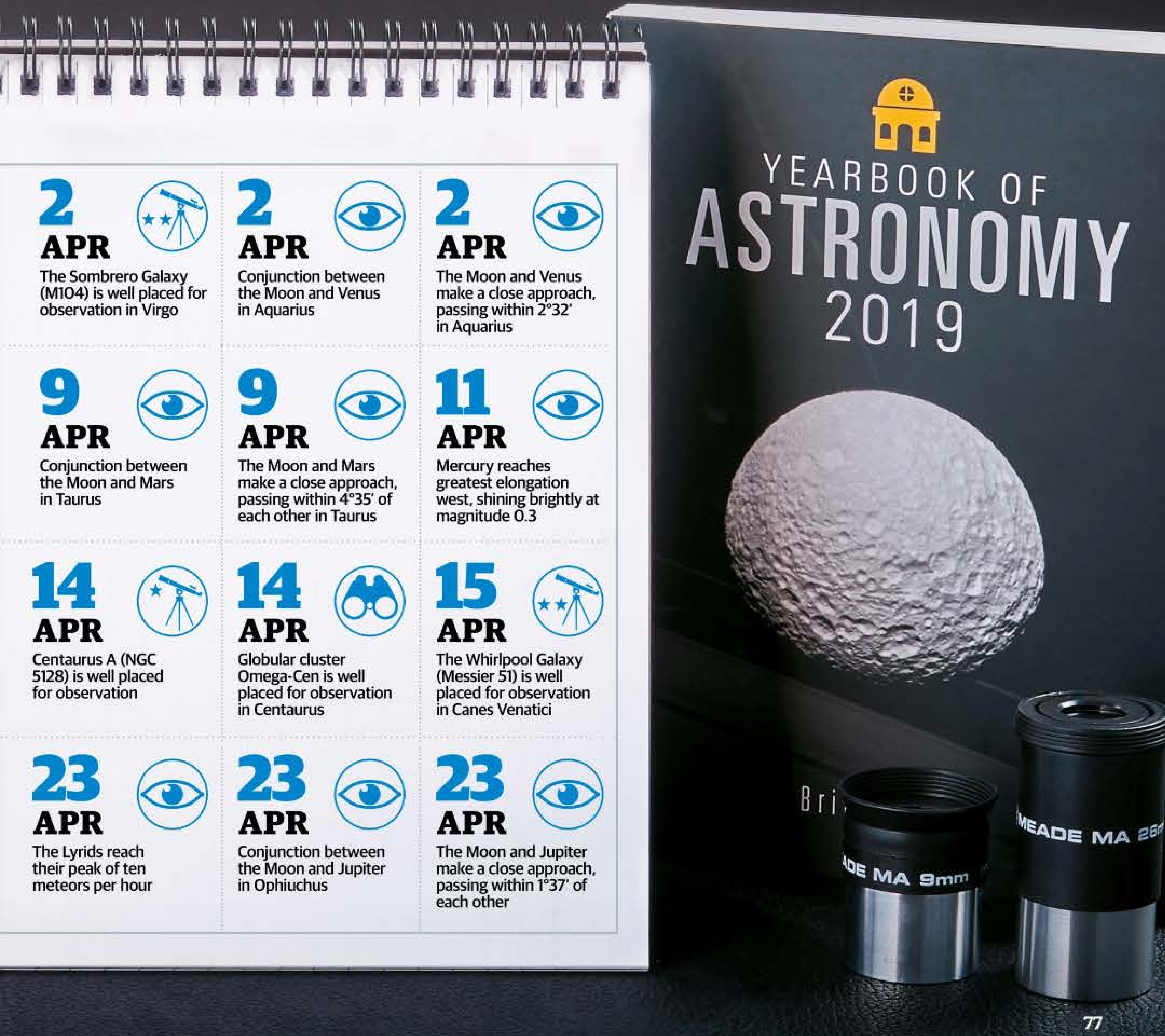
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.



2 APR
The Sombrero Galaxy (M104) is well placed for observation in Virgo

2 APR
Conjunction between the Moon and Venus in Aquarius

2 APR
The Moon and Venus make a close approach, passing within 2°32' in Aquarius

9 APR
Conjunction between the Moon and Mars in Taurus

9 APR
The Moon and Mars make a close approach, passing within 4°35' of each other in Taurus

11 APR
Mercury reaches greatest elongation west, shining brightly at magnitude 0.3

14 APR
Centaurus A (NGC 5128) is well placed for observation

14 APR
Globular cluster Omega-Cen is well placed for observation in Centaurus

15 APR
The Whirlpool Galaxy (Messier 51) is well placed for observation in Canes Venatici

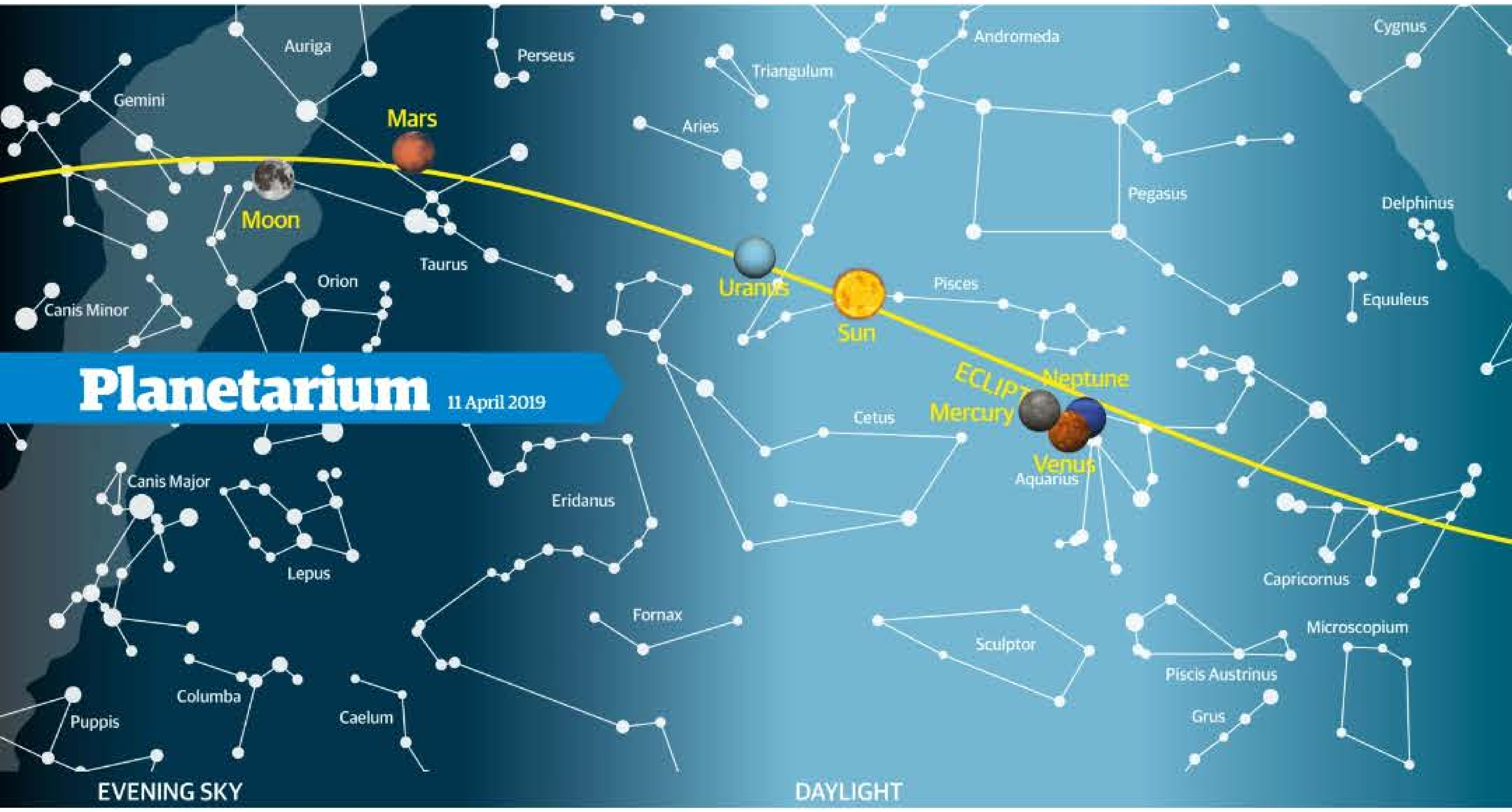
23 APR
The Lyrids reach their peak of ten meteors per hour

23 APR
Conjunction between the Moon and Jupiter in Ophiuchus

23 APR
The Moon and Jupiter make a close approach, passing within 1°37' of each other

Planetarium

11 April 2019



Moon calendar

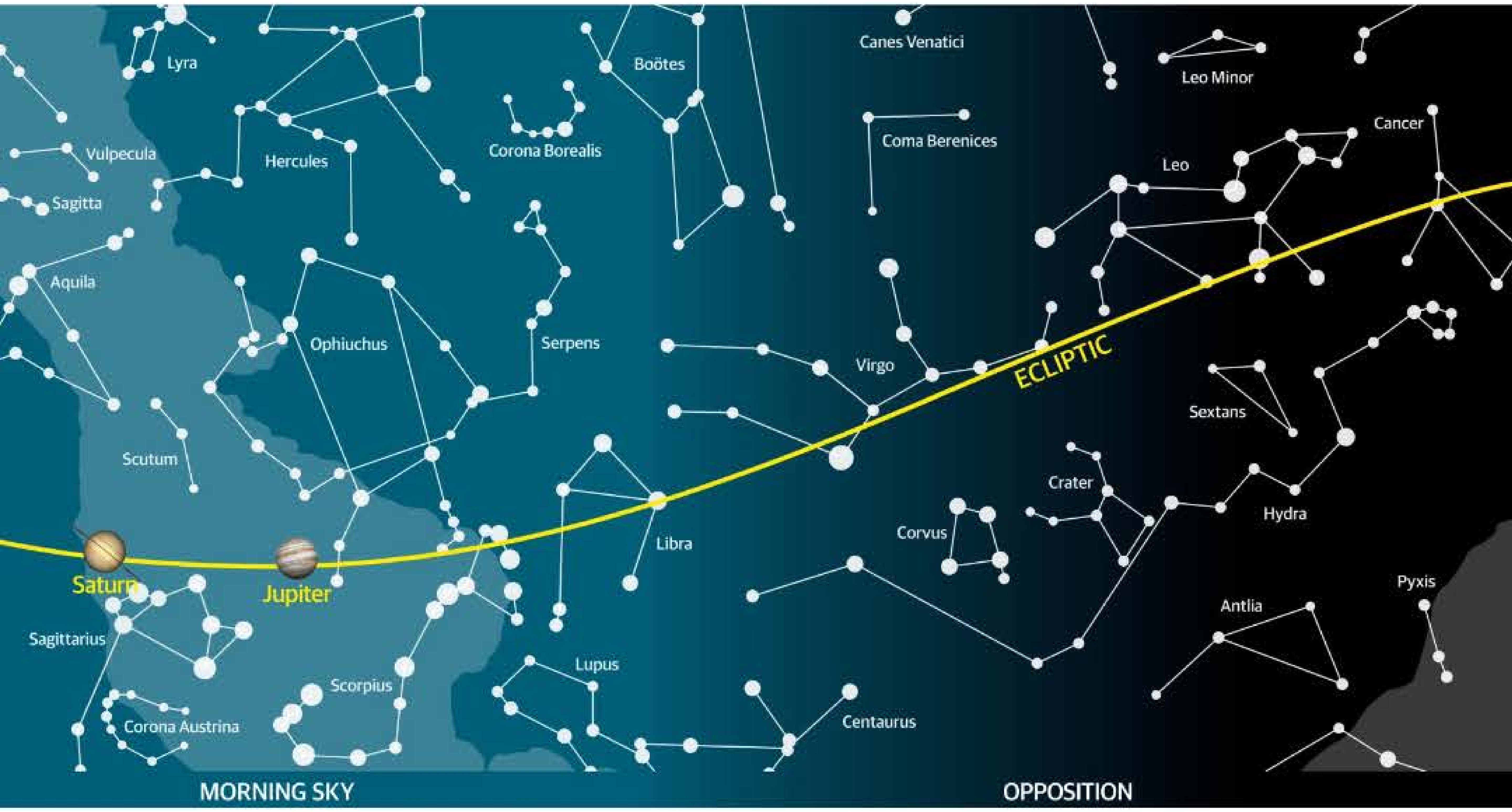
* The Moon does not pass the meridian on 18 April

			28 MAR 49.3% ▲02:07 ▼10:20	**29** MAR 39.4% ▲02:57 ▼11:13	**30** MAR 30.0% ▲03:38 ▼12:11	**31** MAR 21.5% ▲05:11 ▼14:13
1 APR 14.2% ▲05:39 ▼15:17	**2** APR 8.1% ▲06:03 ▼16:23	**3** APR 3.6% ▲06:24 ▼17:29	**4** APR 0.9% ▲06:43 ▼18:36	**5** APR NM 0.2% ▲07:02 ▼19:44	**6** APR 1.6% ▲07:21 ▼20:53	**7** APR 5.1% ▲07:42 ▼22:04
8 APR 10.7% ▲08:06 ▼23:16	**9** APR 18.3% ▲08:35 ▼--:--	**10** APR 27.6% ▼00:27 ▲09:11	**11** APR 38.2% ▼01:34 ▲09:57	**12** APR FQ 49.7% ▼02:35 ▲10:53	**13** APR 61.4% ▼03:28 ▲12:00	**14** APR 72.7% ▼04:11 ▲13:16
15 APR 82.8% ▼04:46 ▲14:37	**16** APR 91.0% ▼05:15 ▲15:59	**17** APR 96.7% ▼05:40 ▲17:22	**18** APR --.-*% ▼06:04 ▲18:44	**19** APR FM 99.5% ▼06:27 ▲20:05	**20** APR 99.4% ▼06:51 ▲21:25	**21** APR 96.6% ▼07:18 ▲22:41
22 APR 91.3% ▼07:49 ▲23:53	**23** APR 84.2% ▼08:26 ▲--:--	**24** APR 75.8% ▲00:57 ▼09:10	**25** APR 66.5% ▲01:51 ▼10:01			

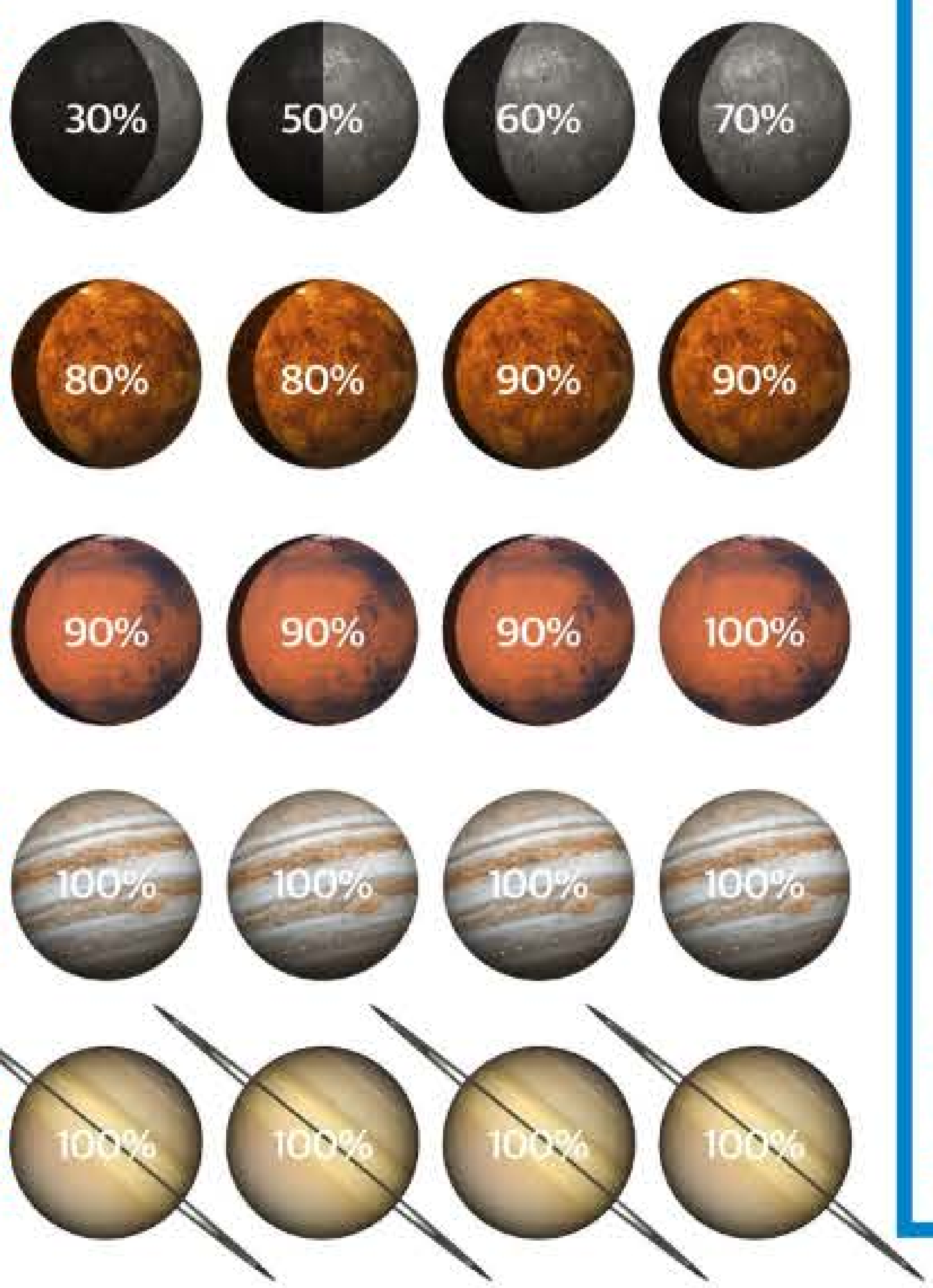
% Illumination
▲ Moonrise time
▼ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



	4 APR	11 APR	18 APR	25 APR
MERCURY	30%	50%	60%	70%
VENUS	80%	80%	90%	90%
MARS	90%	90%	90%	100%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

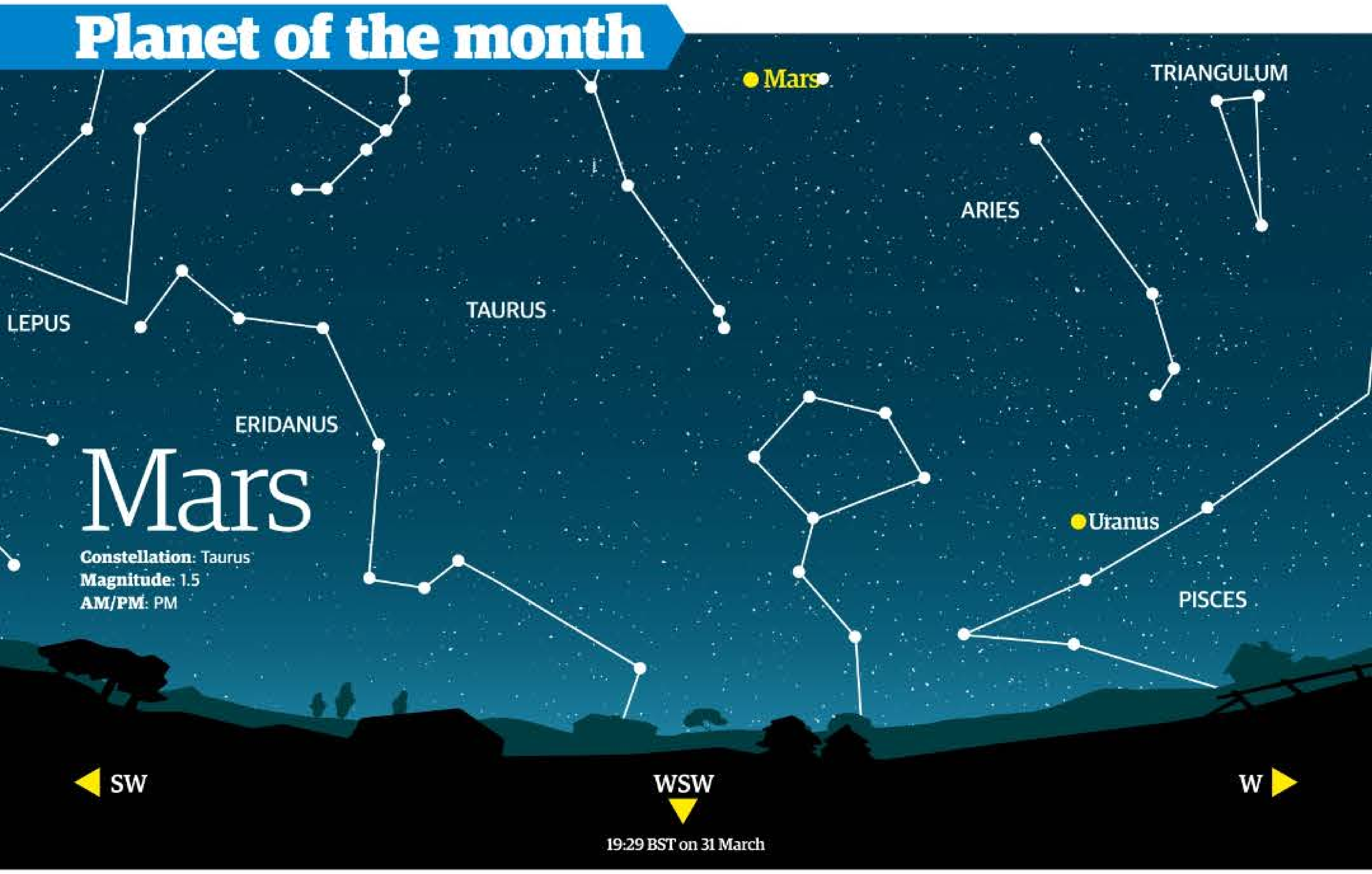
All rise and set times are given in GMT/BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	28 Mar	23h 06m 47s	-04° 55' 34"	Aquarius	1.4	05:06	16:23
	04 Apr	23h 15m 52s	-05° 40' 29"	Aquarius	0.6	05:51	17:01
	11 Apr	23h 37m 09s	-04° 36' 27"	Aquarius	0.3	05:39	17:00
	18 Apr	00h 06m 32s	-02° 06' 03"	Pisces	0.1	05:28	17:15
	25 Apr	00h 41m 50s	+01° 32' 23"	Cetus	-0.1	05:18	17:41
VENUS	28 Mar	22h 13m 50s	-11° 44' 26"	Aquarius	-4.0	04:48	14:55
	04 Apr	22h 46m 11s	-08° 55' 38"	Aquarius	-4.0	05:38	16:15
	11 Apr	23h18m 02s	-05° 54' 17"	Aquarius	-3.9	05:27	16:35
	18 Apr	23h 49m 31s	-02° 44' 11"	Pisces	-3.9	05:15	16:54
	25 Apr	00h 20m 49s	+00° 30' 53"	Pisces	-3.9	05:02	17:15
MARS	28 Mar	03h 40m 23s	+20° 29' 12"	Taurus	1.4	07:21	23:14
	04 Apr	03h 59m 44s	+21° 31' 20"	Taurus	1.5	08:06	00:17
	11 Apr	04h 19m 16s	+22° 24' 53"	Taurus	1.5	07:51	00:15
	18 Apr	04h 38m 58s	+23° 09' 27"	Taurus	1.6	07:38	00:12
	25 Apr	04h 58m 46s	+23° 44' 45"	Taurus	1.6	07:26	00:09
JUPITER	28 Mar	17h 33m 05s	-22° 39' 36"	Ophiuchus	-2.2	01:14	09:10
	04 Apr	17h 34m 03s	-22° 40' 08"	Ophiuchus	-2.3	01:47	09:43
	11 Apr	17h 34m 21s	-22° 40' 15	Ophiuchus	-2.3	01:20	09:16
	18 Apr	17h 33m 59s	-22° 40' 01"	Ophiuchus	-2.4	00:52	08:48
	25 Apr	17h 32m 58s	-22° 39' 25"	Ophiuchus	-2.4	00:24	08:20
SATURN	28 Mar	19h 23m 38s	-21° 37' 41"	Sagittarius	0.6	02:57	11:07
	04 Apr	19h 25m 02s	-21° 35' 07"	Sagittarius	0.6	03:31	11:41
	11 Apr	19h 26m 07s	-21° 33' 10"	Sagittarius	0.5	03:04	11:15
	18 Apr	19h 26m 52s	-21° 31' 53"	Sagittarius	0.5	02:37	10:48
	25 Apr	19h 27m 17s	-21° 31' 18"	Sagittarius	0.5	02:10	10:21

This month's planets

Mars drifts past two beautiful star clusters in Taurus and the Moon this month, while Jupiter and Saturn rise before the Sun

Planet of the month



19:29 BST on 31 March

Mars

Constellation: Taurus
Magnitude: 1.5
AM/PM: PM

You're probably wondering why Mars is this issue's 'Planet of the Month'. After all, although it's easily visible to the naked eye as an orange star, it's not particularly bright – in fact, at magnitude 1.5 it's barely as bright as Regulus, the brightest star in Leo, which is itself only the 22nd-brightest star in the sky. It's not close to us either: last summer, when it was at opposition and blazing like a garnet in the sky, the Red Planet was only 58 million kilometres (36 million miles) away; now it's five-times further away, on the other side of the Sun altogether!

If it were anywhere else in the sky Mars probably wouldn't warrant a second look, but as March draws to a close and April gets into its stride Mars is going to be part of a beautiful gathering of celestial objects in the sky that will be well worth looking for and photographing, too.

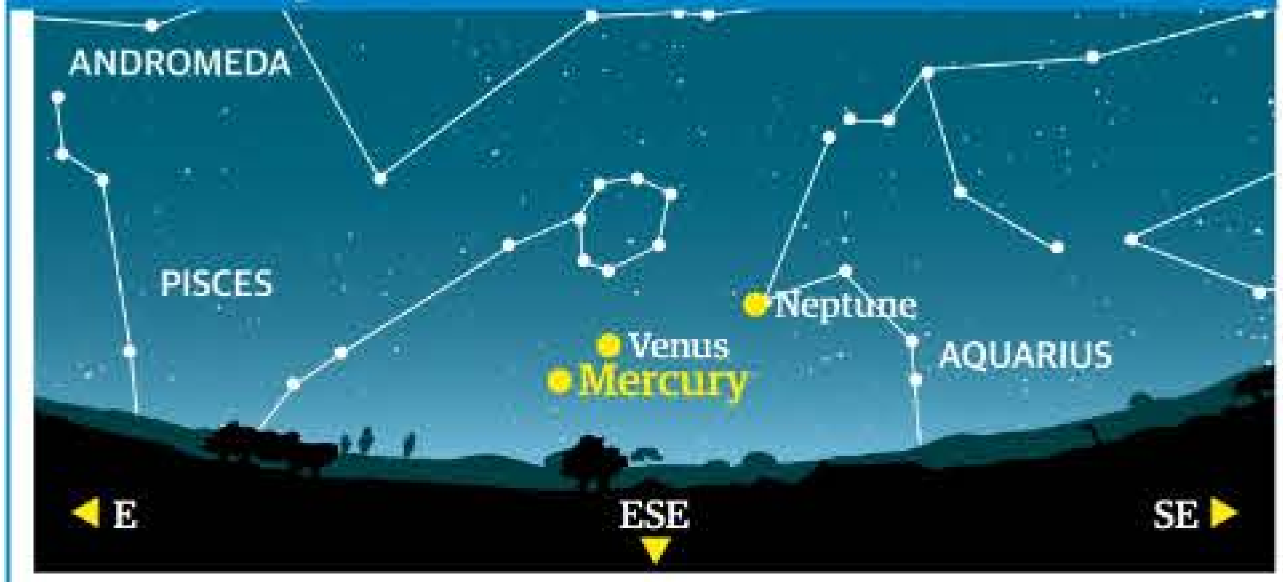
At the end of March Mars will be clearly visible as an orange-yellow star reasonably high up in the west as the sky darkens after sunset. It won't set for several hours after the Sun, so given a clear sky you'll have plenty of time to observe it. Unfortunately, being so far away means its disc is currently tiny, so you'll need a big telescope and high magnification to see any detail on its dusky, dusty surface.

As the twilight deepens on late-March evenings and Mars becomes more obvious you'll notice it has some very interesting company. To its upper right you'll spot the famous Pleiades star cluster, and to the left of Mars you'll see a second star cluster. The V-shaped Hyades cluster represents the horns of Taurus, the Bull, and although it is a lot larger in the sky than the Pleiades it is less obvious for that reason. It does, however, have a very bright star in it: Aldebaran, which is currently brighter than Mars, shining at magnitude 1.0.

On 31 March Mars will be at its closest to the Pleiades, less than three degrees – or six Moon widths – from it. After that the planet will pull away from the cluster, slowly tracking upwards between it and the Hyades, a splendid sight. But it will get even better...

After dark on 8 April a lovely young crescent Moon will shine in the same part of the sky as Mars and the twin star clusters, hanging just beneath them all. On the following evening, the crescent Moon can be found shining just above Aldebaran, to the left of Mars, which will itself be glowing brightly above and to the left of the Pleiades. This tight grouping of planet, Moon and star clusters will be a beautiful sight, and you really must sweep over it with your binoculars if it's clear.

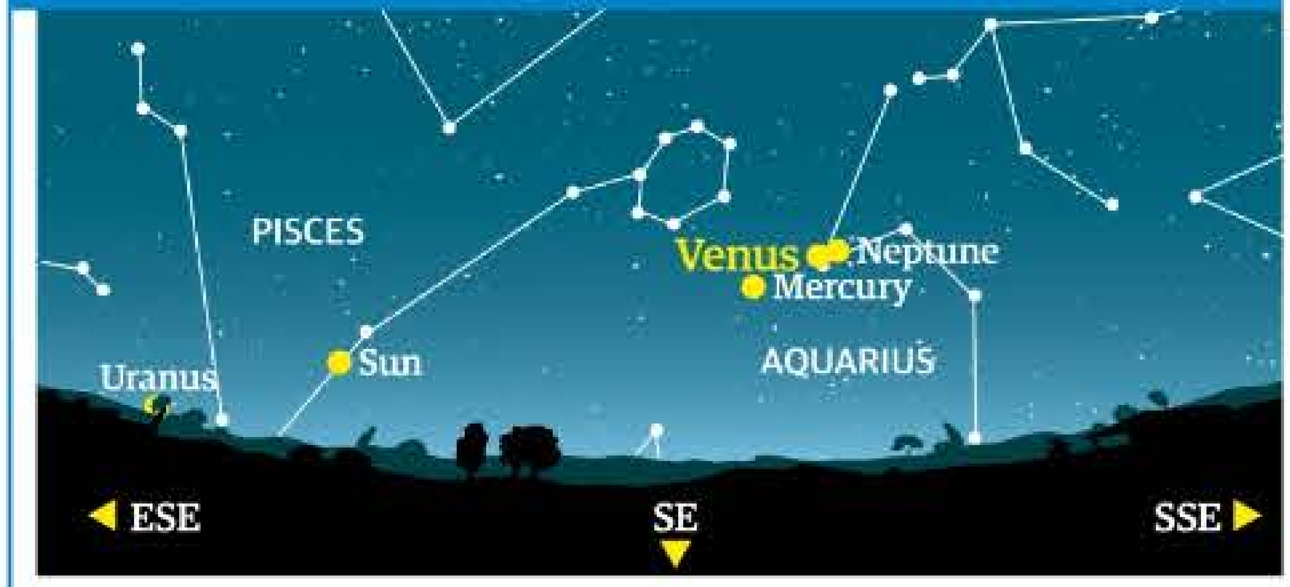
Mercury 06:00 BST on 18 April



Constellation: Aquarius
Magnitude: 1.4
AM/PM: AM

If you are a fan of the closest planet to the Sun then sadly this is not going to be a good month for you. Mercury, named after the winged messenger of the Gods in Roman mythology, is technically a morning object, but it is just too close to the Sun in the morning sky to be seen during our observation period.

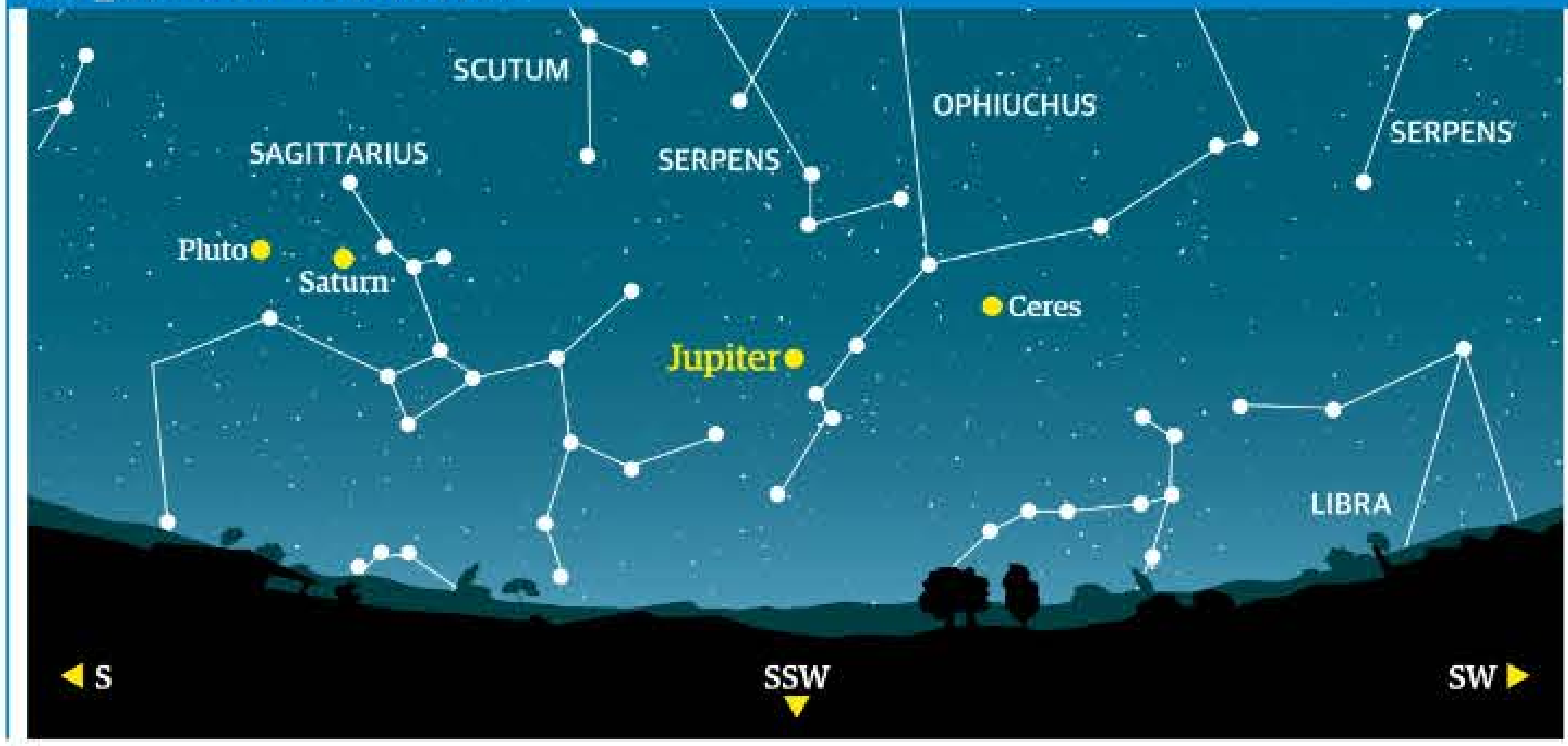
Venus 07:00 BST on 10 April



Constellation: Aquarius into Pisces
Magnitude: -4
AM/PM: AM

This is not going to be a good month for you if you enjoy the thrilling sight of Venus blazing in your sky. The second planet from the Sun will be a 'Morning Star', but so close to the Sun, and rising so soon before it, that even with an impressive visual magnitude of -4 it will be very hard to spot in the bright pre-dawn sky.

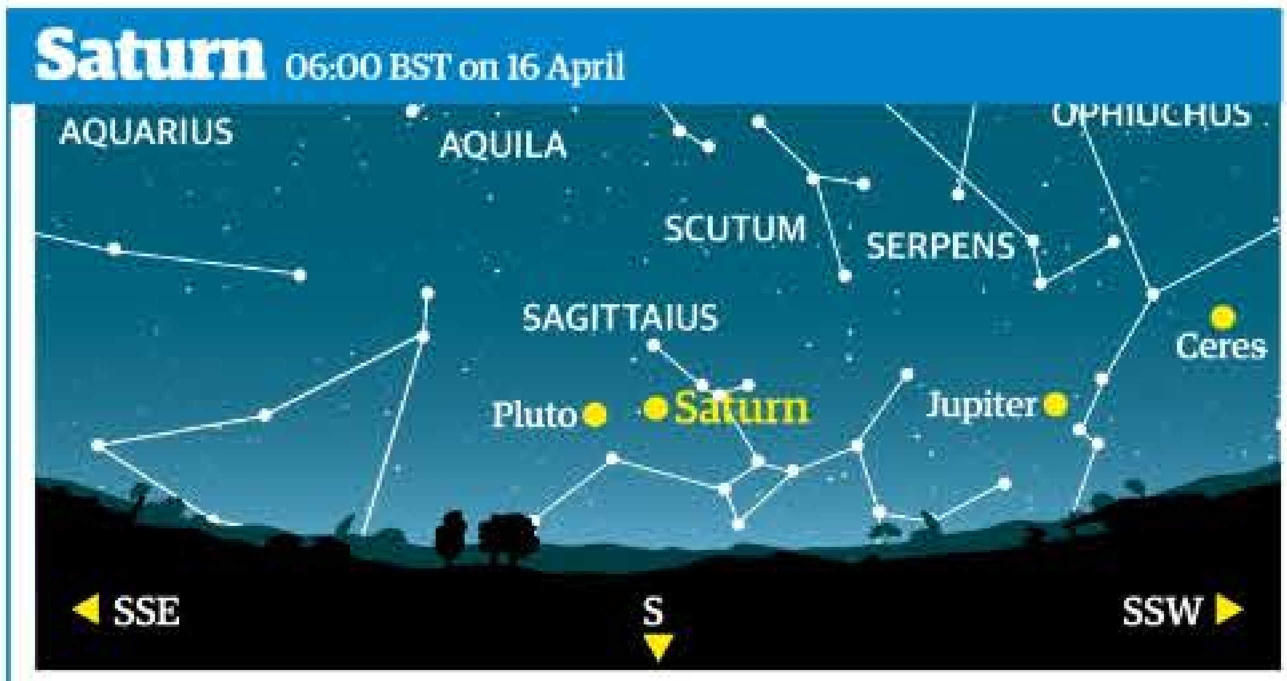
Jupiter 07:00 BST on 10 April



Constellation: Ophiuchus
Magnitude: -2.2
AM/PM: AM

The largest world in our Solar System will be rising at around 2am at the start of our observing period, and by the time April is drawing to a close will be rising an hour earlier. It will be highest this month at around 4am, when it will be easy to spot as a bright blue-white 'star' reasonably high in the southern sky. You'll find Jupiter to the upper right of fainter Saturn, embedded in the rich star clouds of the Milky Way, a short distance to the right of the famous Lagoon and Trifid nebulae. Look out for a beautiful Moon shining close to Jupiter before dawn on 27 March.

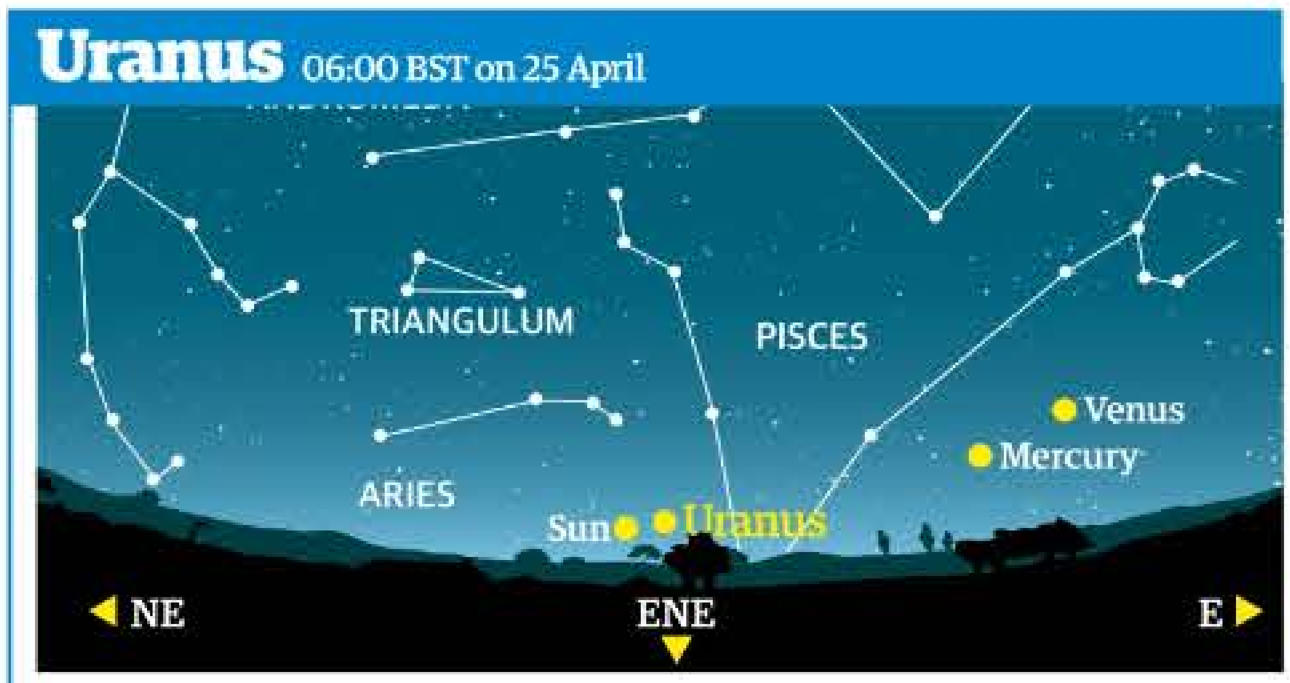
Saturn 06:00 BST on 16 April



Constellation: Sagittarius
Magnitude: 0.5
AM/PM: AM

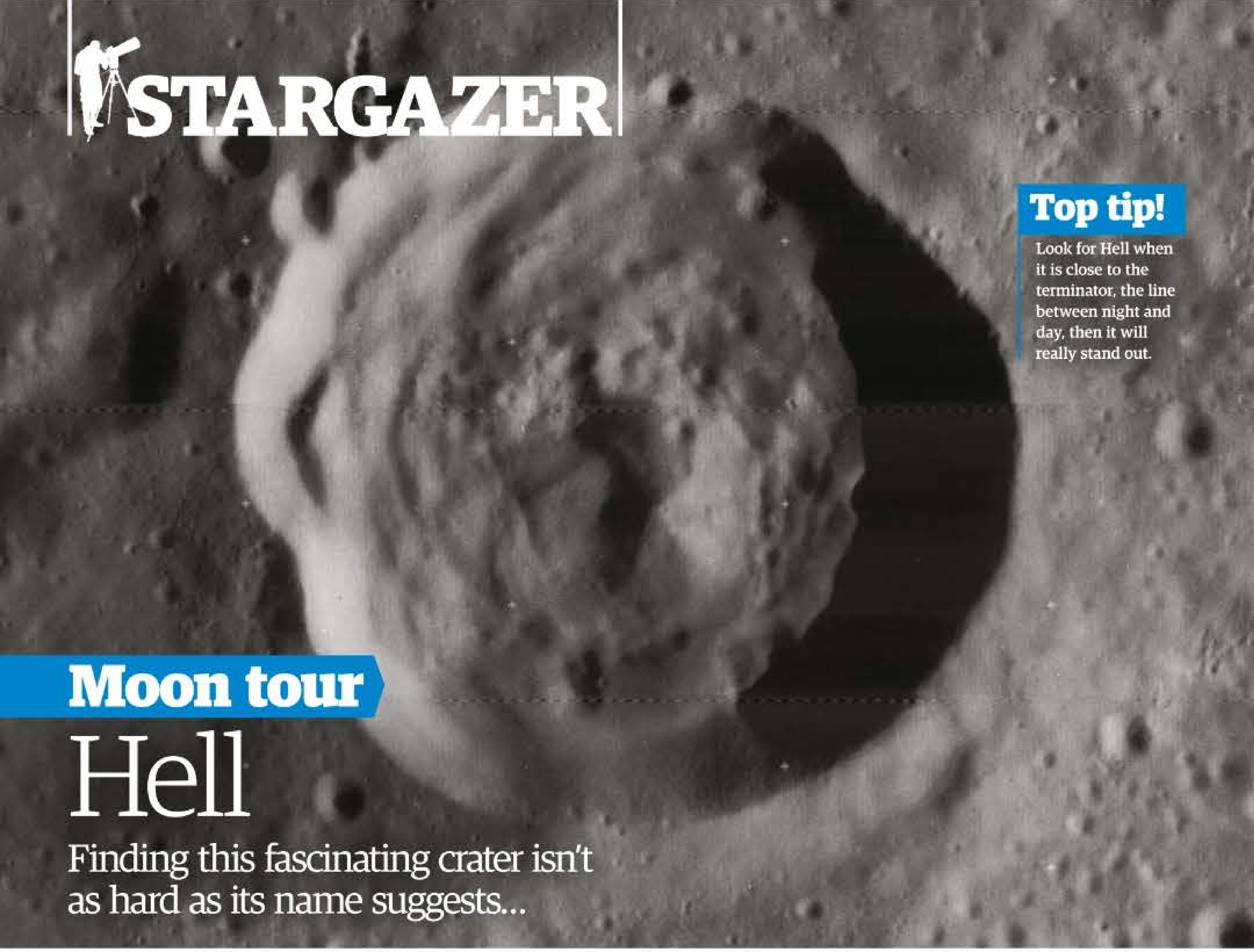
Saturn will be an easy naked-eye object before dawn this month, shining to the left of the handle of the famous 'Teapot' asterism of Sagittarius. If you look for Saturn around 3am, before the sky starts to brighten, you'll find it low in the southeast, down to the lower left of much higher and brighter Jupiter.

Uranus 06:00 BST on 25 April



Constellation: Aries
Magnitude: 5.9
AM/PM: PM

At the end of March Uranus is visible in the evening sky after sunset, low in the west, but with each passing day it will draw closer to the Sun - by early April it will essentially be lost from view. At magnitude 5.9 Uranus is technically visible to the naked eye. However, binoculars or a telescope will help you find it.



Moon tour

Hell

Finding this fascinating crater isn't as hard as its name suggests...

Top tip!

Look for Hell when it is close to the terminator, the line between night and day, then it will really stand out.

The lunar landscape down towards and around its south pole is wild, craggy and rugged; a raw, bare-rock wilderness of walled plains, huge craters and towering mountains all blasted out by a brutal asteroid bombardment many millennia ago. Down there in the southern lunar highlands there are too many craters to count: they overlap and overlay each other. The most ancient large craters have smaller, younger craters inside them, and many of those smaller craters have even smaller, even younger craters inside them.

Exploring this cluttered landscape through a telescope is both thrilling and bewildering – there's so much to see! Naturally the huge impact craters of Clavius, Maginus and Tycho draw the eye, but a little further to their north and east lies a much smaller crater with a short but intriguing name that few people know about, and even fewer have ever taken a good look at while touring the huge features around it.

Compared to the giant wounds around it Hell is a small impact crater. With a diameter of 33 kilometres (20.5 miles) it is just a third as wide as nearby Tycho, and its depth of 2.2 kilometres (1.4 miles) makes it half as deep as that better-known crater. But this small crater, which lies in the western half of the sprawling Deslandres walled plain, offers a lot to the lunar observer willing to drag their gaze away from the 'celebrity features' around it.

Roughly circular, Hell's rim is sharp but otherwise quite unremarkable. The crater's main appeal is the complicated nature of its floor: it is covered with countless lumps and bumps which really stand out when the crater is near the terminator and the Sun is hitting the crater floor at a low angle. At high magnification Hell's floor is a fascinating sight, and the features on its floor form a subtle spiral shape.

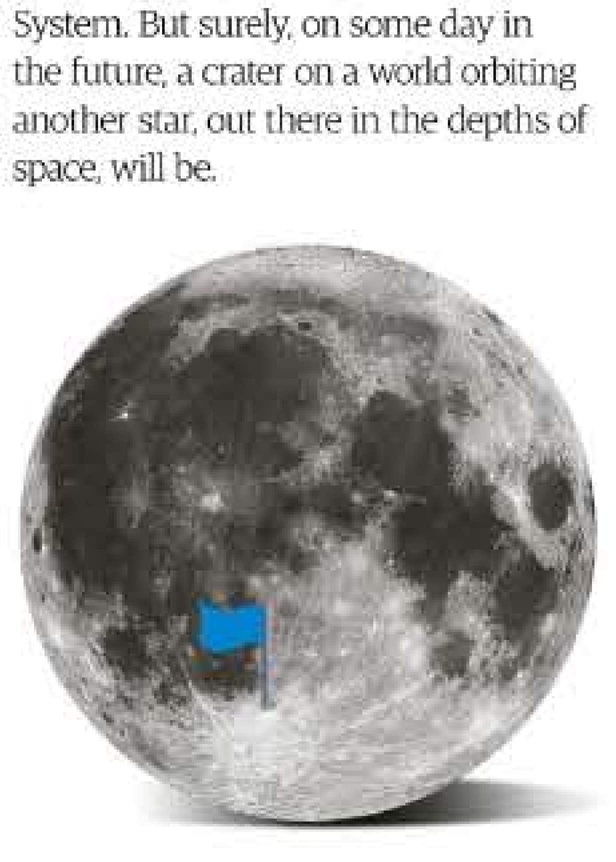
When Hell was formed millions of years ago, a huge amount of debris was thrown up by the impact; debris which rained down on the landscape around it in a blizzard of boulders, rocks and stones. This hail of wreckage blasted 19 smaller 'satellite' craters out of the surface around Hell, and it's fun to tour these through your telescope using a high-magnification eyepiece.

So when can you see this crater for yourself this month?

At the start of our observing period Hell is just ahead of the terminator, and hard to see, but a medium or large telescope should still be able to pick it out from the surface as a dark pit. By 30 March the crater will have vanished from view, swallowed up by the inky blackness of lunar night. Hell will reappear as the Moon reaches its first quarter phase on the evening of 13 April. As the terminator sweeps over it, and the Sun's low, slanting rays shine down into it, Hell will be a striking sight through a telescope, looking like a skull's empty eye socket. Over the next few evenings the crater will become more and more illuminated but less obvious, and by full Moon on 19 April will resemble a light ring with a dark interior. But unlike many lunar craters Hell won't vanish at full Moon, it will still be quite easy to see. On 27 April the terminator will sweep back over the crater, stealing it from our view.

But what about that intriguing name? Why is a crater on the silent, dusty, dead Moon named after a place where the souls of the damned writhe in a sea of fire and flame? Actually, it isn't. Hell was named in honour of a Hungarian astronomer and Jesuit priest, Maximilian Hell. In 1756 Hell became the director of the Vienna Observatory, and 13 years later travelled to the far north of Norway to observe the 1769 transit of Venus.

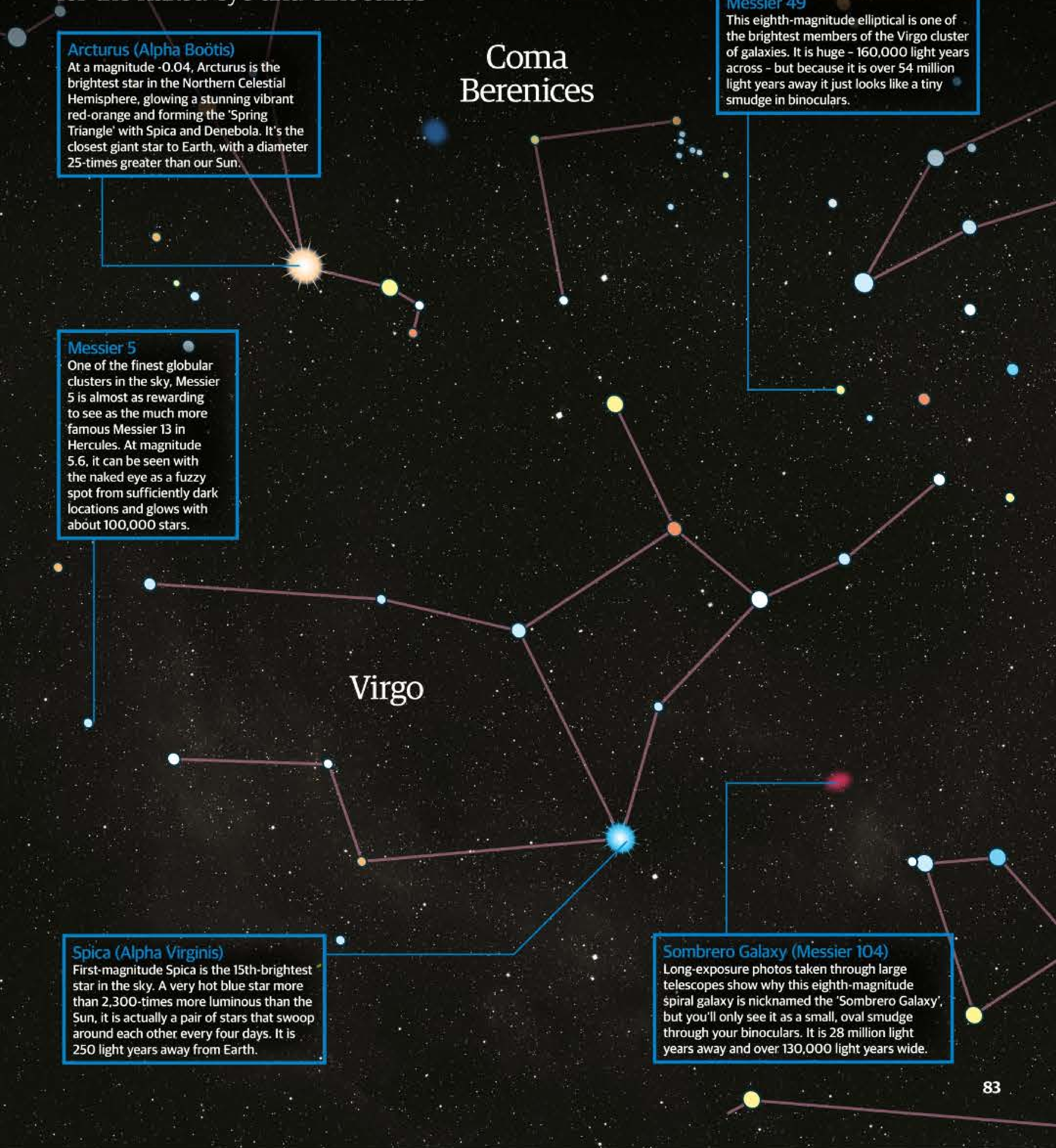
And is there a 'Heaven' crater on the Moon, for the sake of balance? Sadly not, nor on any other planet in the Solar System. But surely, on some day in the future, a crater on a world orbiting another star, out there in the depths of space, will be.



© NASA

Naked eye & binocular targets

The spring sky offers some treats for the naked eye and binoculars



Arcturus (Alpha Boötis)
At a magnitude -0.04, Arcturus is the brightest star in the Northern Celestial Hemisphere, glowing a stunning vibrant red-orange and forming the 'Spring Triangle' with Spica and Denebola. It's the closest giant star to Earth, with a diameter 25-times greater than our Sun.

Messier 5
One of the finest globular clusters in the sky, Messier 5 is almost as rewarding to see as the much more famous Messier 13 in Hercules. At magnitude 5.6, it can be seen with the naked eye as a fuzzy spot from sufficiently dark locations and glows with about 100,000 stars.

Messier 49
This eighth-magnitude elliptical is one of the brightest members of the Virgo cluster of galaxies. It is huge - 160,000 light years across - but because it is over 54 million light years away it just looks like a tiny smudge in binoculars.

Spica (Alpha Virginis)
First-magnitude Spica is the 15th-brightest star in the sky. A very hot blue star more than 2,300-times more luminous than the Sun, it is actually a pair of stars that swoop around each other every four days. It is 250 light years away from Earth.

Sombrero Galaxy (Messier 104)
Long-exposure photos taken through large telescopes show why this eighth-magnitude spiral galaxy is nicknamed the 'Sombrero Galaxy', but you'll only see it as a small, oval smudge through your binoculars. It is 28 million light years away and over 130,000 light years wide.

How to...

Observe spring galaxies

We might have lost the glittering star clusters and colourful nebulae of the winter sky for another year, but this month offers the chance to dive into the depths of the universe

You'll need:

- ✔ Binoculars or a small telescope
- ✔ Dark-sky observing site
- ✔ Star chart or planetarium phone/tablet app

During the long, cold winter months we're really quite spoiled. That chilly season has the most brightly coloured stars, the most glittering clusters and, in the Orion Nebula, one of the most beautiful sights in the whole sky too. It's easy to feel a little deflated when they all sink into the west and winter turns into spring, but don't feel too downhearted - the spring sky is rich with another type of object, and for many astronomers this is the best time of the year because they have an opportunity to gaze through their telescopes into the deepest, darkest depths of the universe and see objects almost unimaginably far away: galaxies.

Of course there are galaxies available for observation during every season, but during spring there is an almost ridiculous number of them visible, many of them gathered together in one small part of one constellation that is visible all night long. The Virgo Cluster contains around 1,300 galaxies and can be found on the constellation's northern border with Coma Berenices. The cluster is spread across almost eight degrees of the sky (16 Full Moon widths) and contains a mixture of spiral and elliptical galaxies. The centre of the cluster lies 54 million light years from us, and its most distant members are more than 100 million light years away.

Finding the Virgo Cluster is really easy. All you need to do is find the Virgo constellation in the sky, then train your binoculars or telescope on the correct part of it. Luckily, finding this patch of sky is easy: you just have to follow the arc of the Big Dipper's handle down to Arcturus in Boötes, then drive a spike to Spica, the brightest star in Virgo. Then follow the constellation's shape to the top right, and there you'll find dozens of faraway galaxies to explore.

In order to identify the galaxies, you'll need a star chart from a book or magazine, or a planetarium app on your phone or tablet, to identify which galaxy is which, but if you haven't access to those don't worry - you can just slowly sweep the area with whatever equipment you've got and drink in the view. If you're new to observing this cluster, it's important to not expect too much - you're unlikely to see great amounts of galactic detail due to their enormous distances from Earth.

Each tiny smudge that's visible is in fact an enormous group of stars so far away that their light was emitted from them around the same time as the dinosaurs were perishing in the aftermath of the asteroid impact!

Tips & tricks

Don't expect too much

Photos of the galaxies always look spectacular, but be aware that through your binoculars or telescope they will just look like small, faint smudges.

Don't rush

Make sure your eyes are fully dark-adapted before you start hunting.

Steady as she goes

Put your binoculars on a tripod if you can.

Go slowly

The galaxies are very small and faint, and if you move your binoculars or telescope too quickly you'll skip right over them.

Use a chart

If you want to know which galaxy is which you'll need to use a labelled star chart from a magazine or book.

Seeking out your galaxies

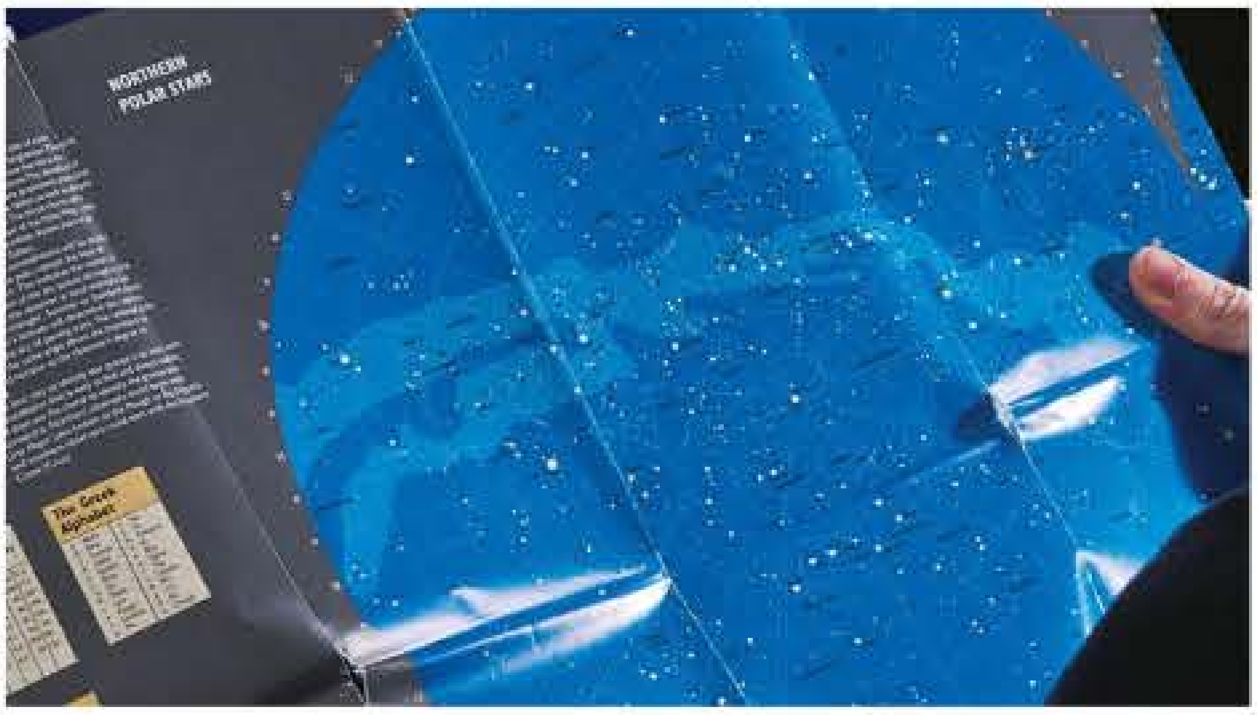
Great great views of some of the faintest deep-sky targets

On a clear night from a site with no light pollution the brightest members of the cluster are visible in binoculars as tiny smudges, almost like out-of-focus stars. However, a small telescope will really improve their appearance and show you many more of them too. You'll need a star chart from a book or magazine, or a planetarium app on your phone or tablet, to identify which galaxy is which.

Send your photos to
space@spaceanswers.com

1 **Pick the right night**
A clear night with no Moon is perfect for going galaxy hunting. Find an out-of-the-way observing site with a dark sky unspoiled by light pollution.

2 **Dark adapt**
Once you've reached your observing site, wait at least half an hour for your eyes to adapt to the darkness before starting your galaxy hunt.



3 **Star hop to Virgo**
Find Virgo in the sky by following the 'arc' of the Big Dipper's handle to Arcturus, then by 'driving a spike' to Spica.

4 **Eyes on the prize**
Locate the Cluster area with your naked eye before trying to use any observing equipment. It's slightly to the lower left of Denebola in Leo.

5 **Sweep the sky**
Slowly sweep your binoculars over that area of sky. The galaxies will look like very small, very faint grey smudges with their low magnification.

6 **Try your telescope**
A telescope will show you many more galaxies than binoculars, and more detail in the brightest and largest members of the cluster too.

Messier 58

Deep sky challenge

Explore the galaxies of Virgo

There's a gaggle of glowing galactic delights to gaze at through your telescope this spring

The winter sky is dominated by bright star clusters and nebulae, and of course summer belongs to the misty star clouds of the Milky Way, but spring is the best time of the year for astronomers who enjoy hunting down faint, distant galaxies in the night sky. This month if you swing your telescope towards Virgo around midnight you'll be able to see a whole spray of them in that constellation, on and straddling the border with its more northerly neighbour, Coma Berenices.

Part of the much larger 'Virgo Supercluster' of galaxies, the Virgo Galaxy Cluster is itself a vast collection of elliptical and spiral galaxies - more than 1,300 of them in total - the centre of which lies 54 million light years away. Long-exposure photos, which can record its faintest members, show it spans approximately eight degrees in the night sky, the equivalent of 15 full Moons. The cluster's brightest members can be seen in binoculars or small telescopes. However, larger instruments reveal many more, much fainter and more interesting galaxies embedded within this fascinating, enormous object. Through medium-aperture instruments the Virgo Cluster galaxies just resemble small, fuzzy patches, but 12" and larger telescopes will start to reveal structure within them, such as the spiral arms and the bright central cores of many of the cluster's most interesting members.

NGC 4567 and NGC 4568

Messier 86

1 Messier 58

At magnitude 9.6 this spiral galaxy is best seen with 8" and larger telescopes. Smaller telescopes are too small to resolve its mottled spiral arms.

2 Messier 84

This magnitude 9 elliptical galaxy is one of the brightest members of 'Markarian's Chain', a string of galaxies best seen through large telescopes. It looks like an elongated, oval-shaped fuzzy patch.

3 Messier 86

Another bright member of 'Markarian's Chain', this magnitude 8.8 elliptical galaxy is visible through medium- to large-aperture telescopes as a roughly round, misty patch of light.

4 Messier 87

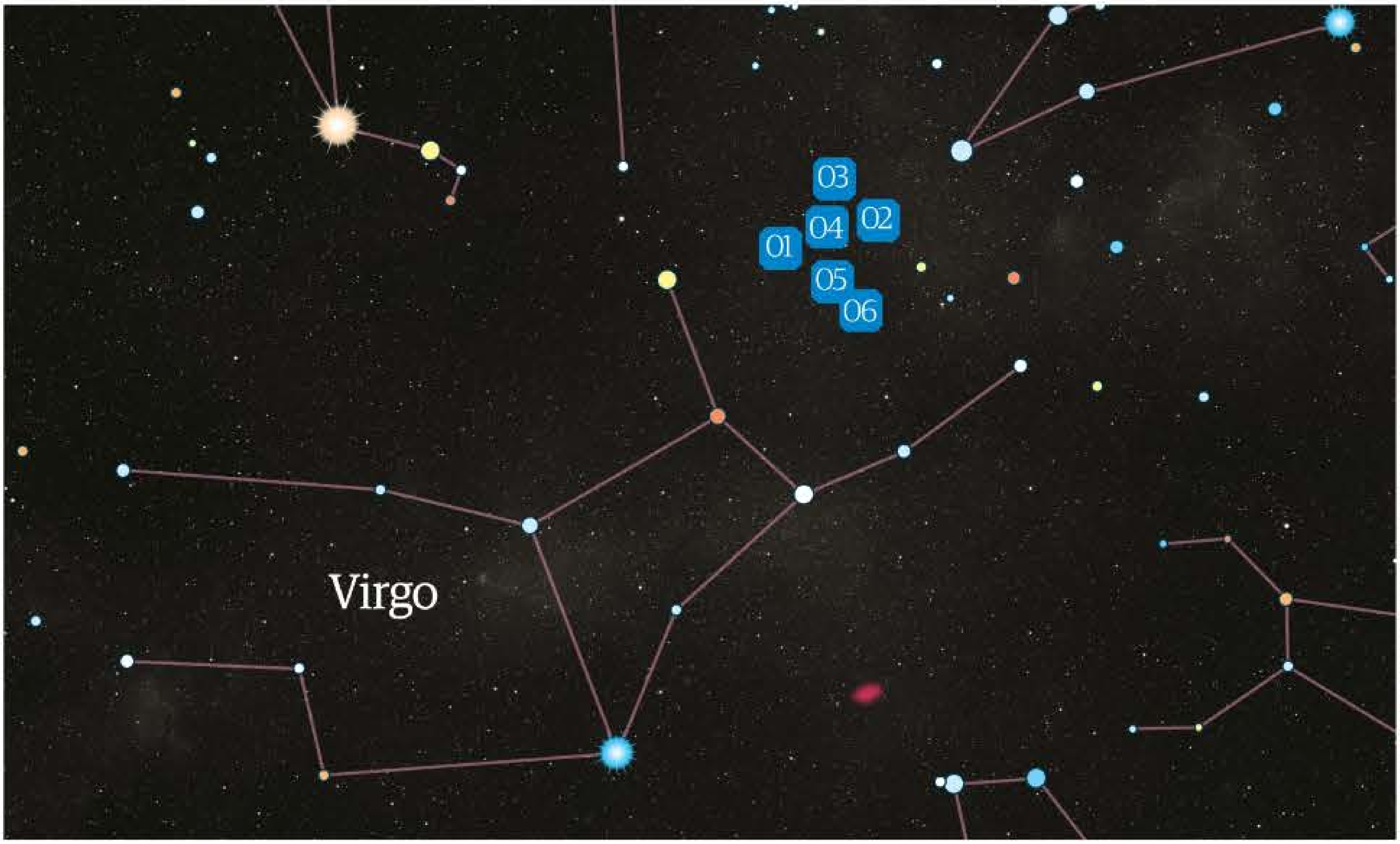
This giant elliptical galaxy is the largest and brightest in the Virgo Cluster. At magnitude 8.7 it is visible in small telescopes, but under high magnification larger instruments give glorious views.

5 NGC 4567

Fainter than its 'Siamese Twin' NGC 4568, this magnitude 11.2 face-on spiral galaxy can only be seen properly with telescopes of 6" aperture or larger. It lies 98 million light years from Earth.

6 NGC 4568

This magnitude 10.8 spiral appears superimposed in front of neighbouring galaxy NGC 4567. Large telescopes using high magnification will show it as an extended smudge of pale light.



© NASA; ESA; Adam Block/Mount Lemmon SkyCenter/University of Arizona

The Northern Hemisphere

Some bright stars of winter still linger after sunset, but spring lets us gaze out of the Milky Way's plane

Bright yellow-white star Capella of Auriga (the Charioteer) sits low in the northwestern sky this month, a striking sight at magnitude 0.08 alongside easy-to-locate Castor and Pollux of Gemini (the Twins).

Ursa Major's 'Big Dipper' is the simplest asterism to find as soon as darkness falls, making it easy to use its pointer stars to find Polaris. Follow the pointers in the other direction and you will find bright-white star Regulus in Leo (the Lion); trace your finger along the bowl and you'll find yourself led to brilliant yellow-orange star Arcturus in the constellation of Boötes (the Herdsman). Nearby, just northeast of Arcturus, you'll be greeted by the unmistakable semi-circle of the Northern Crown, Corona Borealis.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

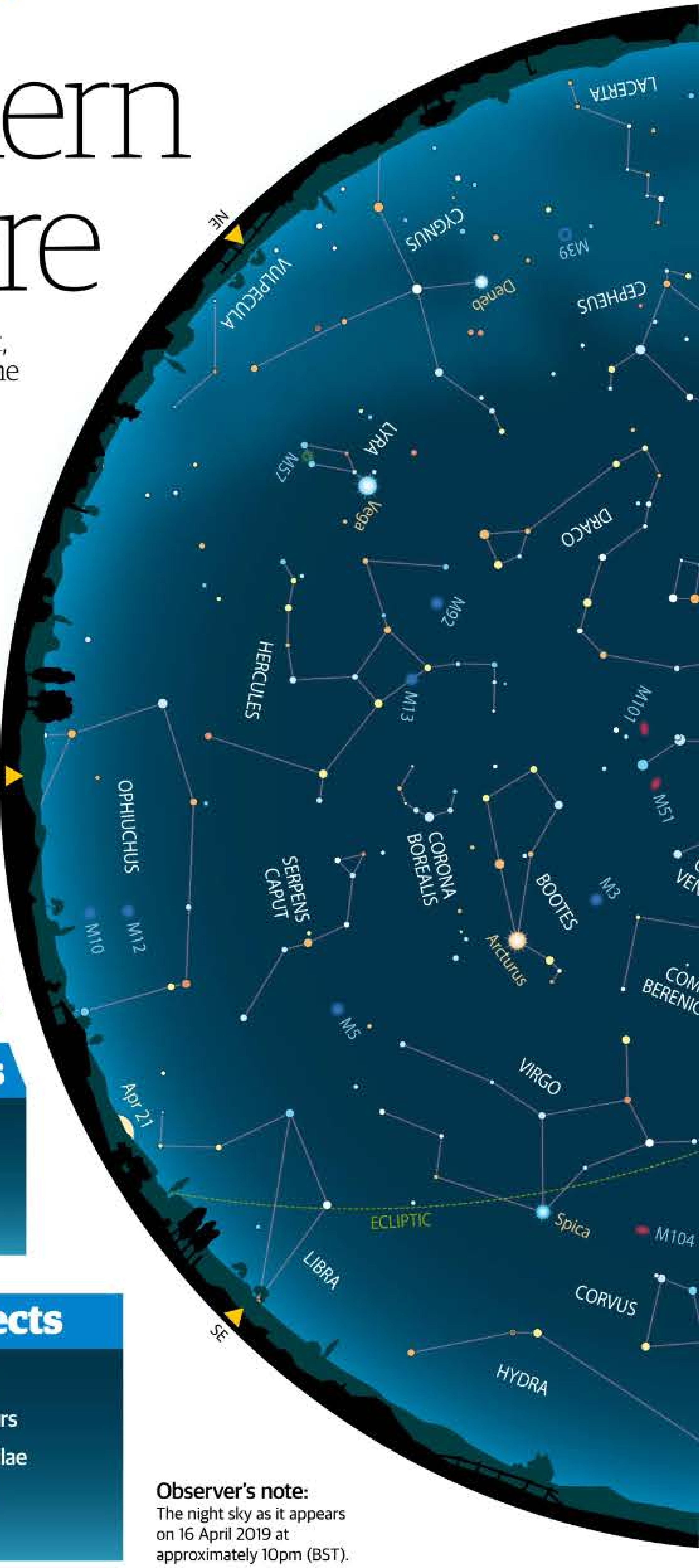
- ● Sirius (-1.4)
- ● -0.5 to 0.0
- ● 0.0 to 0.5
- ● 0.5 to 1.0
- ● 1.0 to 1.5
- ● 1.5 to 2.0
- • 2.0 to 2.5
- • 2.5 to 3.0
- • 3.0 to 3.5
- · 3.5 to 4.0
- · 4.0 to 4.5
- · Fainter
- · Variable star

Spectral types

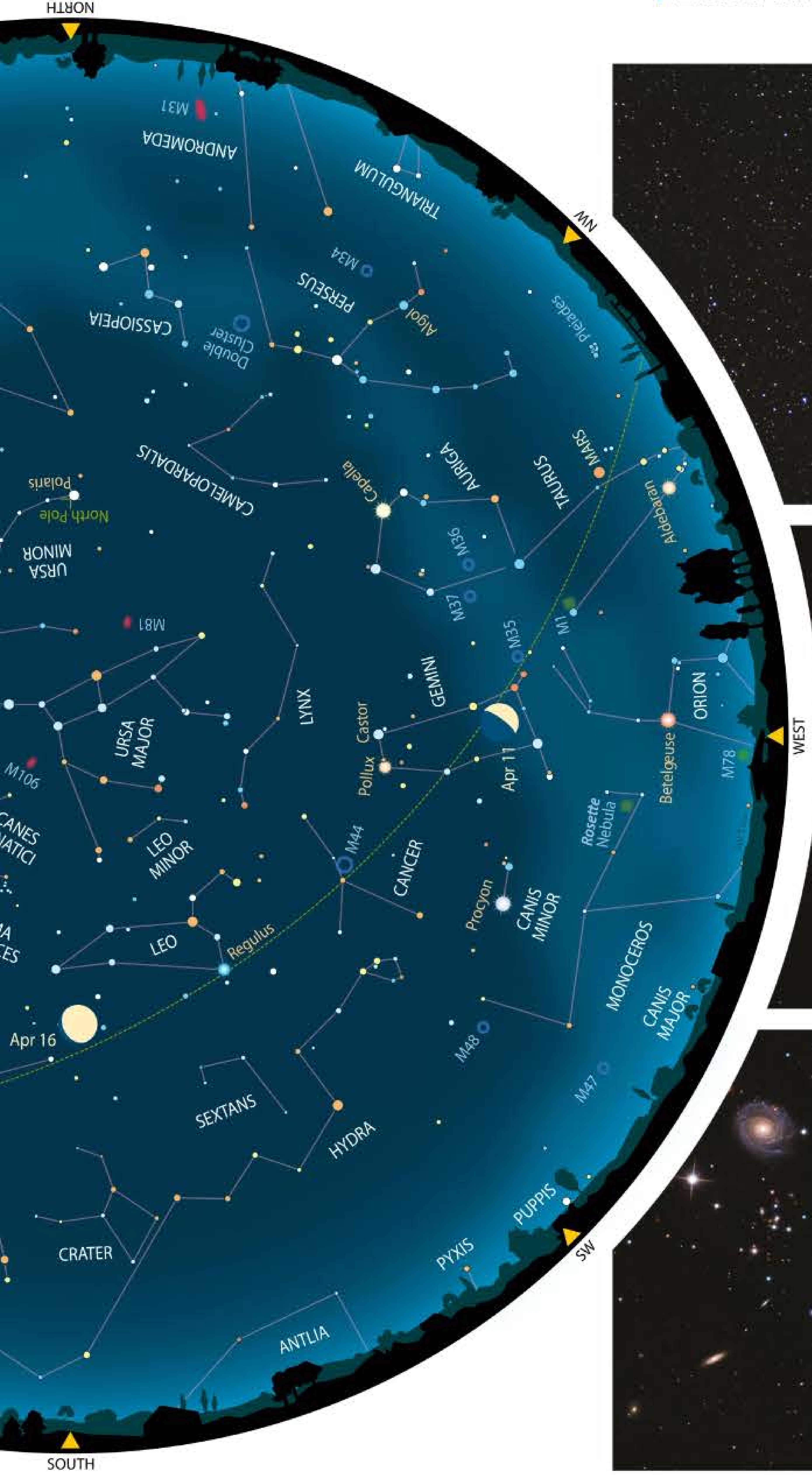
● ●	O-B	● ●	G
● ●	A	● ●	K
● ●	F	● ●	M

Deep-sky objects

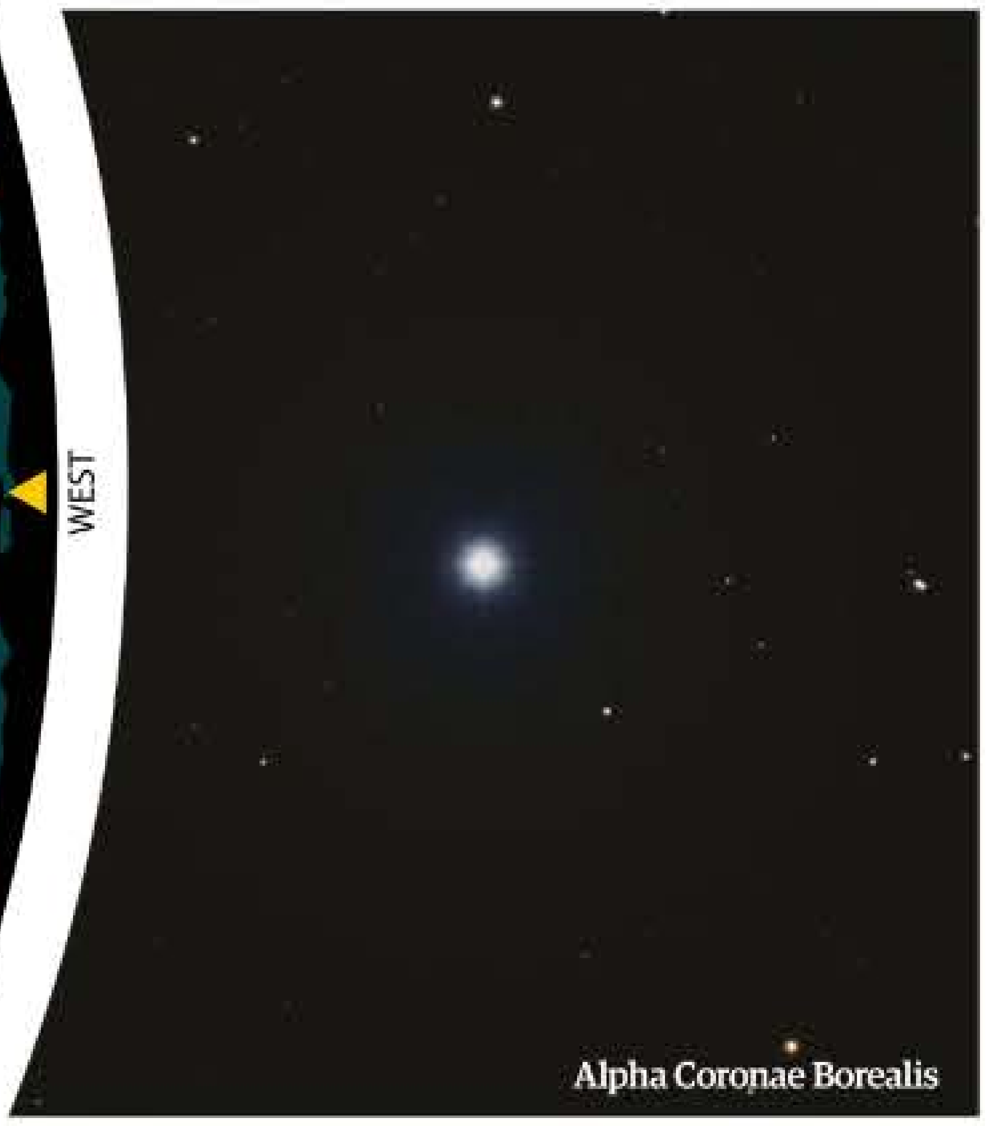
- ○ ○ Open star clusters
- ● ● Globular star clusters
- ■ ■ Bright diffuse nebulae
- ○ ○ Planetary nebulae
- ● ● Galaxies

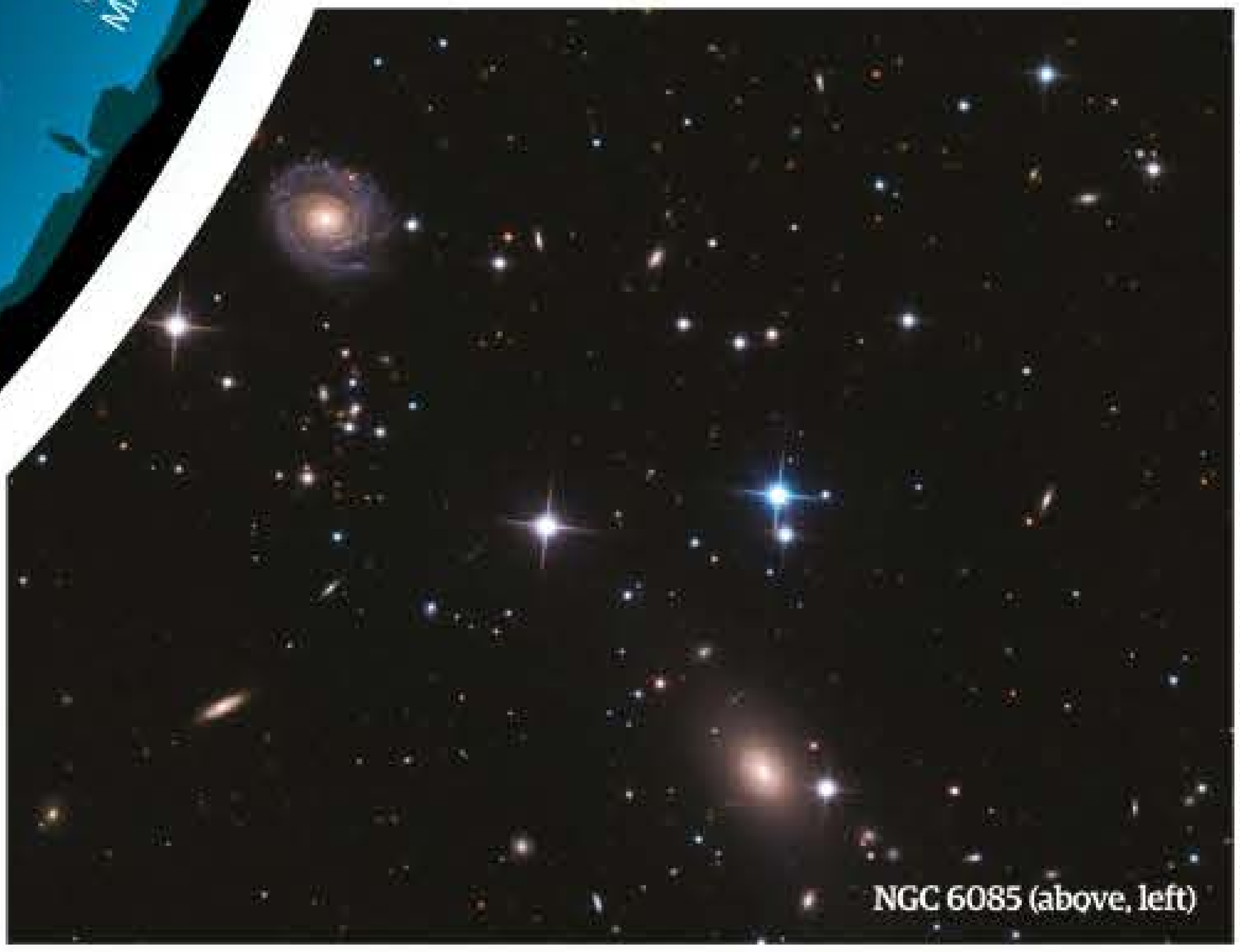


Observer's note:
The night sky as it appears on 16 April 2019 at approximately 10pm (BST).



Messier 37

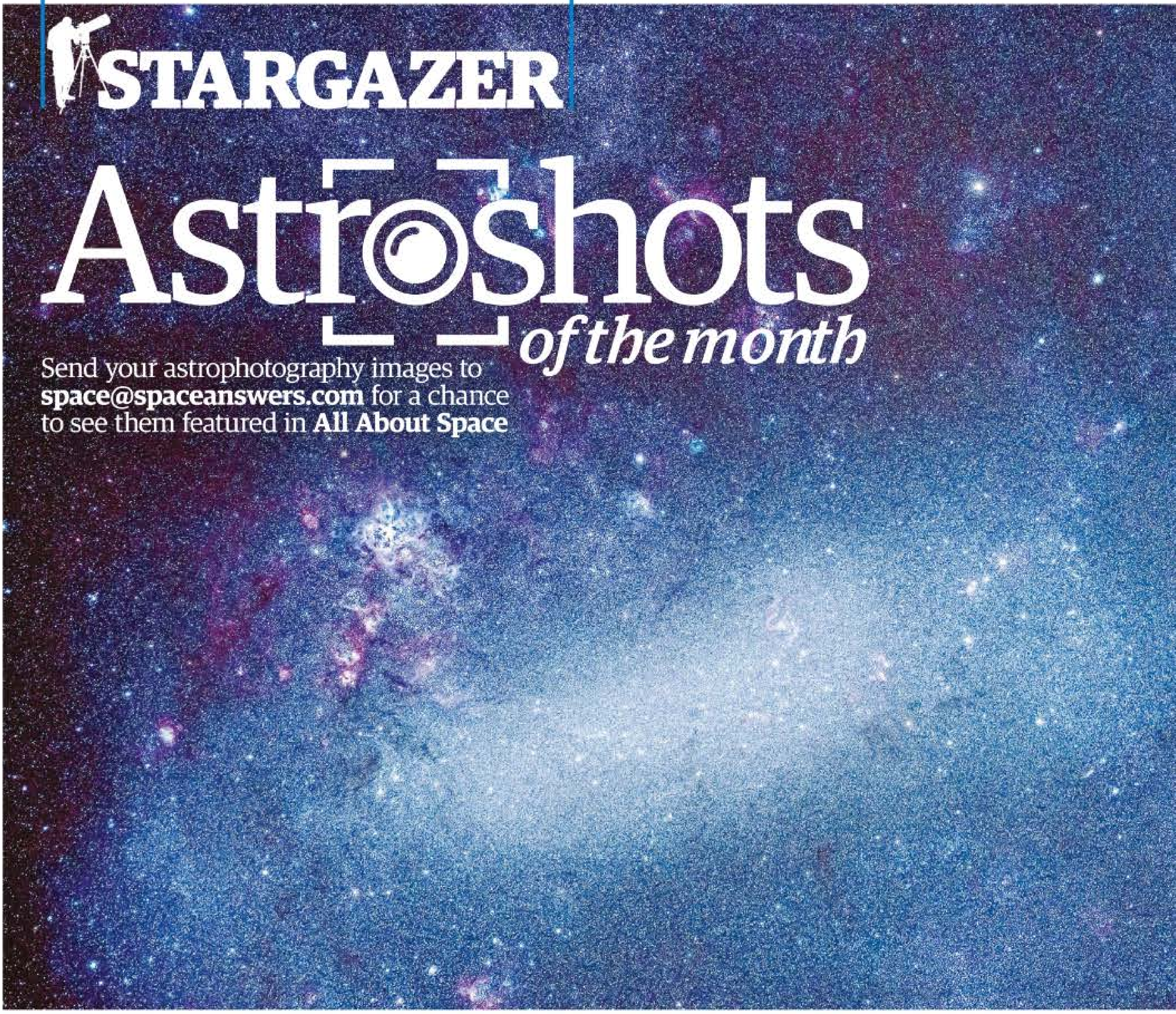

Alpha Coronae Borealis


NGC 6085 (above, left)

© Wil Tirion; Ole Nielsen; Adam Block/Mount Lemmon SkyCenter/University of Arizona; David Ritter

Astroshots of the month

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**



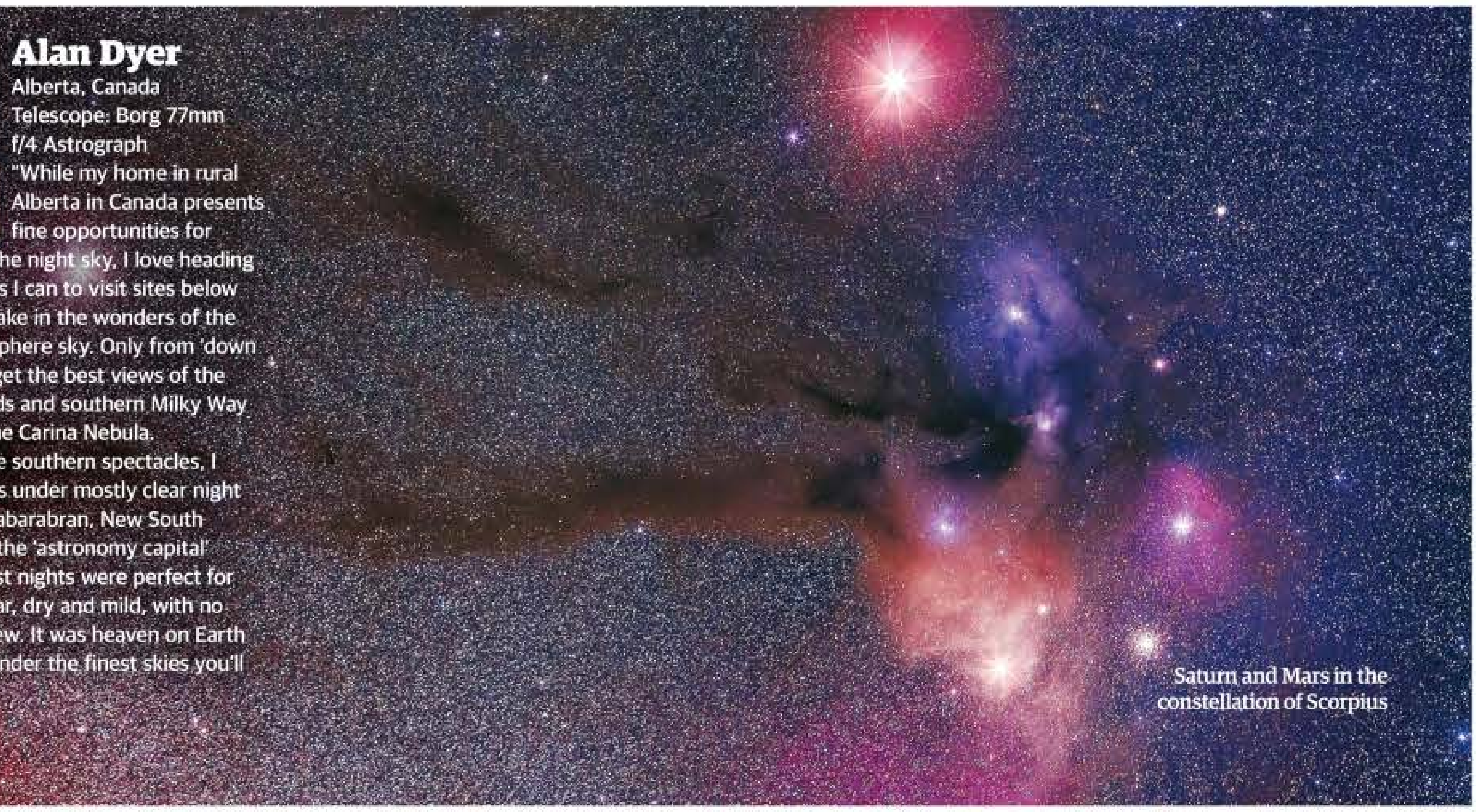
Alan Dyer

Alberta, Canada

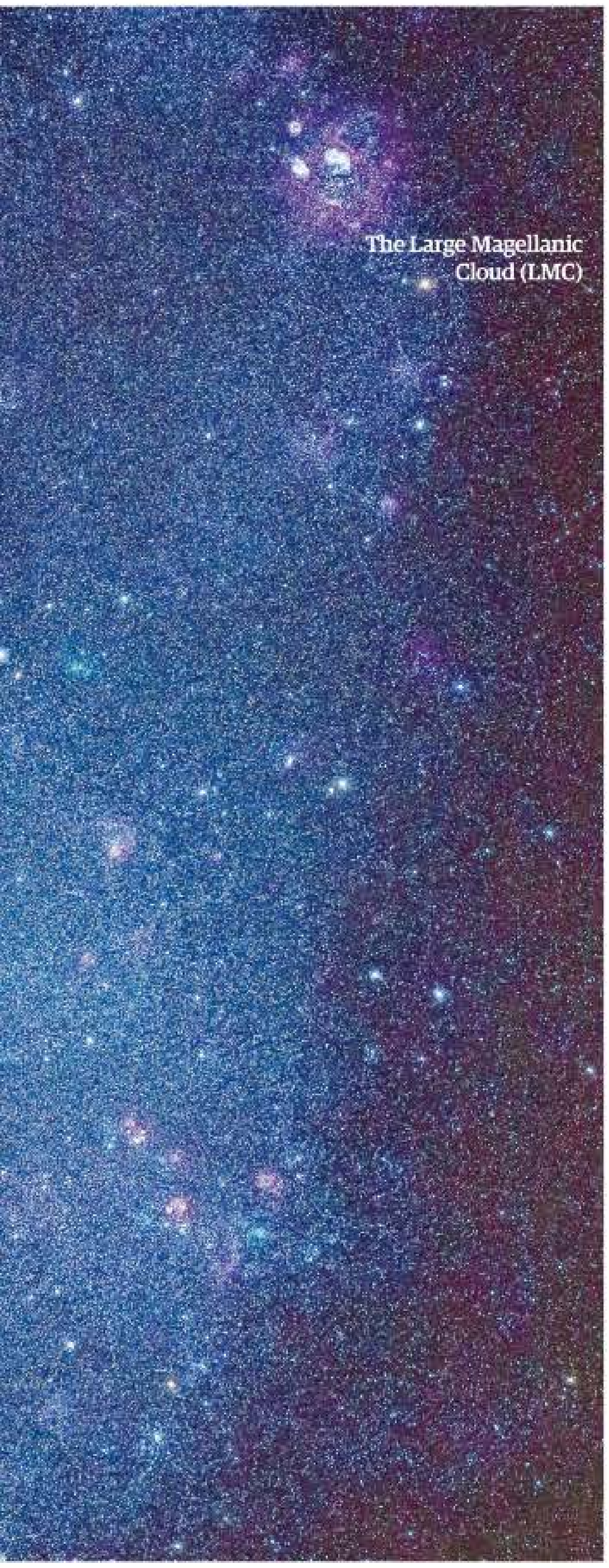
Telescope: Borg 77mm f/4 Astrograph

"While my home in rural Alberta in Canada presents fine opportunities for photographing the night sky, I love heading south as often as I can to visit sites below the equator to take in the wonders of the Southern Hemisphere sky. Only from 'down under' can you get the best views of the Magellanic Clouds and southern Milky Way sights such as the Carina Nebula.

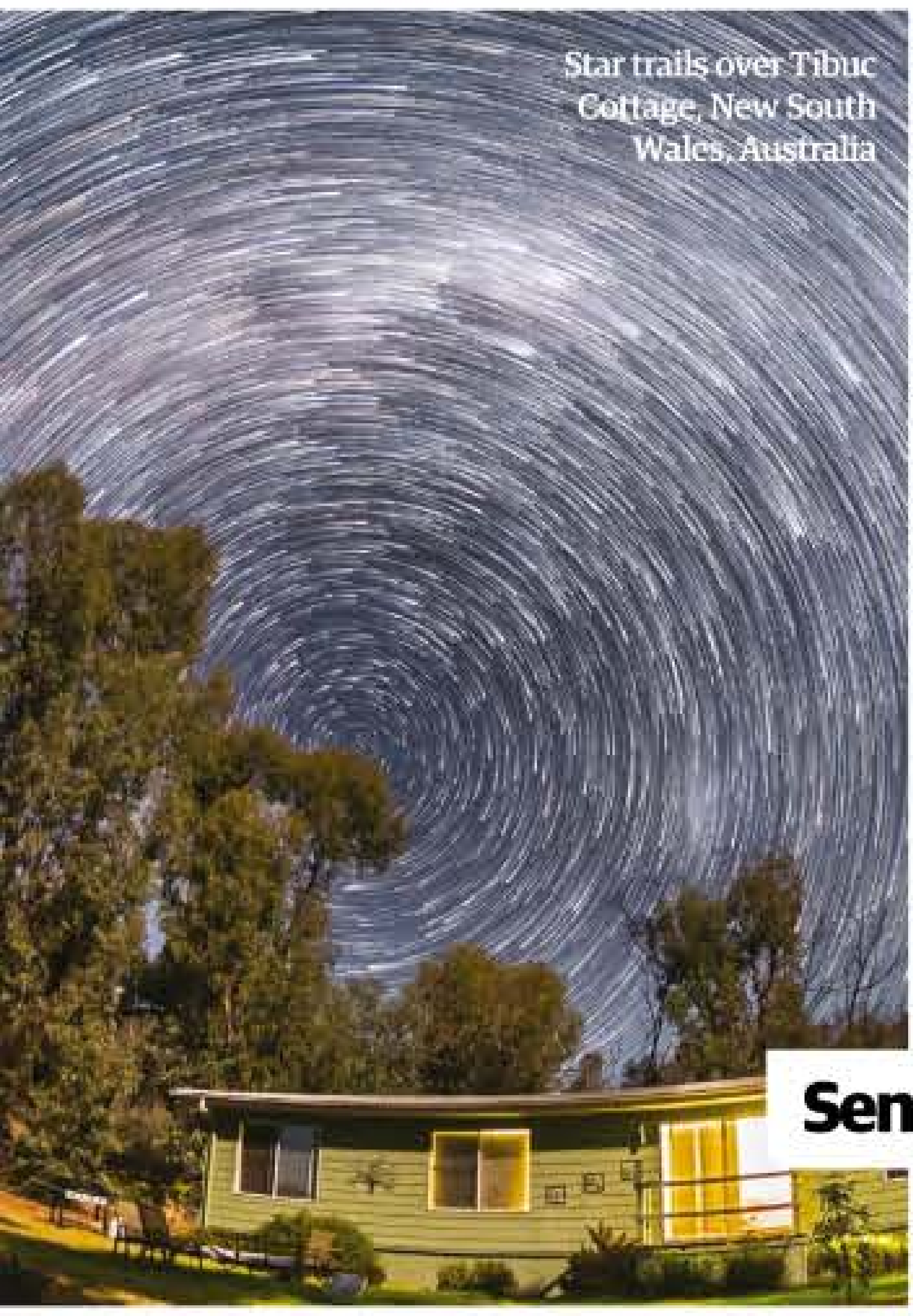
To capture the southern spectacles, I spent two weeks under mostly clear night skies near Coonabarabran, New South Wales, billed as the 'astronomy capital' of Australia. Most nights were perfect for astronomy – clear, dry and mild, with no wind, bugs or dew. It was heaven on Earth for stargazing: under the finest skies you'll find anywhere."



Saturn and Mars in the constellation of Scorpius



The Large Magellanic Cloud (LMC)



Star trails over Tibuc Cottage, New South Wales, Australia

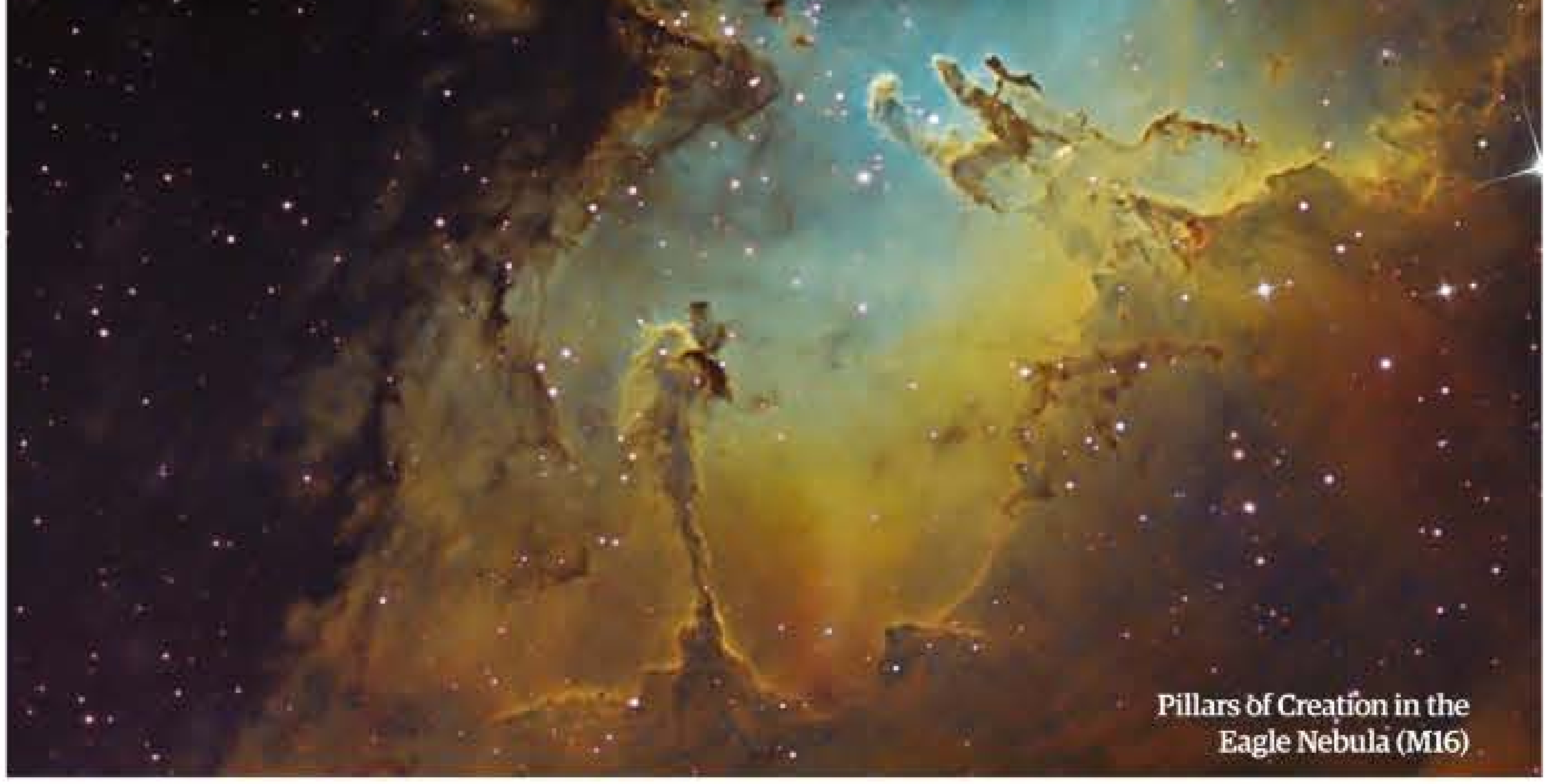
Terry Hancock

Michigan, United States

Telescope: 12" Ritchey-Chrétien reflector and Takahashi E180 Astrograph

"My interest in astronomy and photography began some 40 years ago in Australia. Inspired by the late Sir Patrick Moore, my first telescope was a 4.5-inch Newtonian, and I enjoyed many nights in the pollution-free, dark, southern night skies of the hot Australian outback. It was often so dark that the Milky Way cast a shadow on the ground.

"The skies are mediocre in Michigan where I observe from these evenings. I pride myself in taking really long exposures of deep-sky objects and always try to maintain a natural look."



Pillars of Creation in the Eagle Nebula (M16)

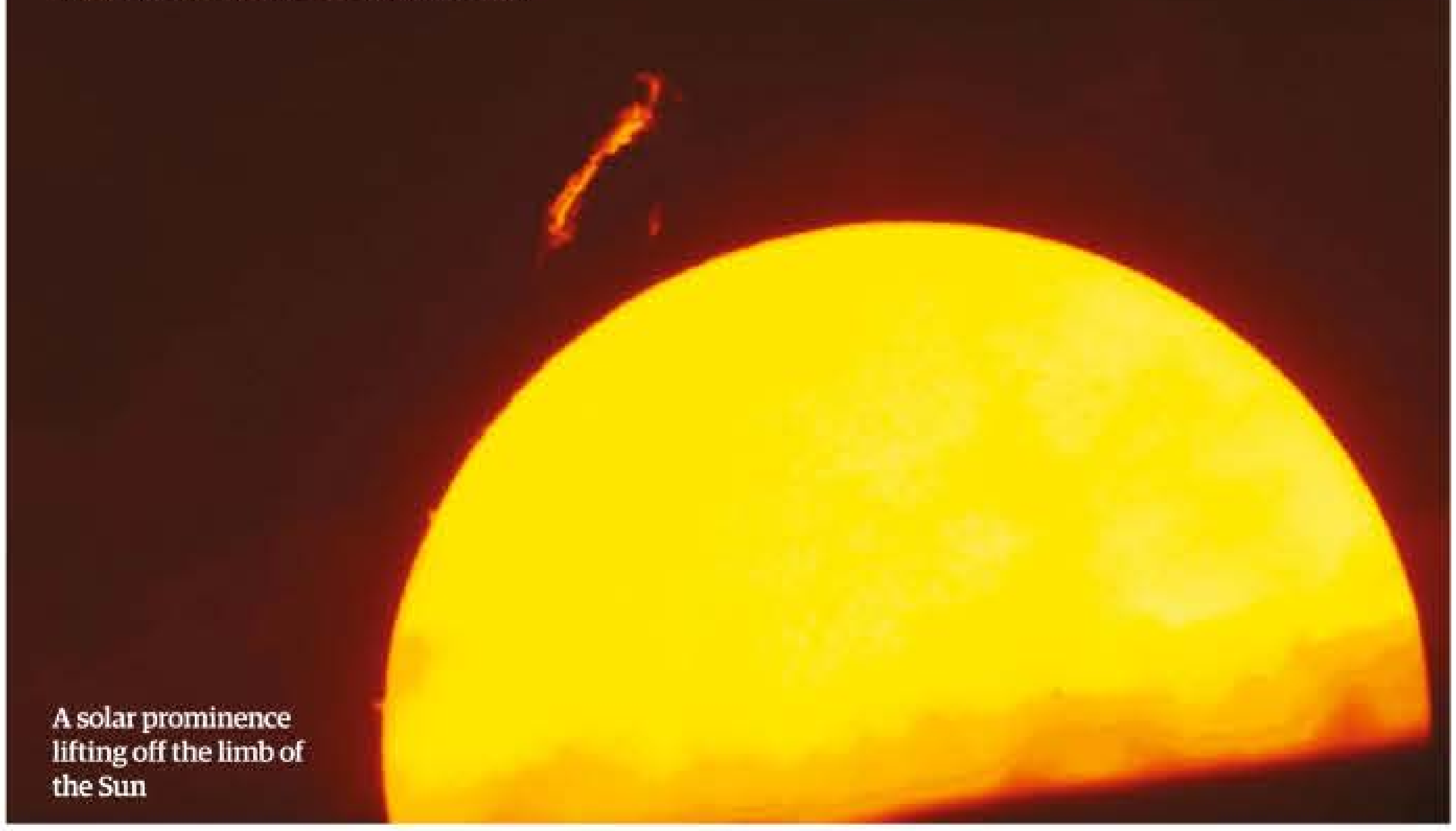
Samuel Bleyen

Dublin, Ireland

Telescope: Solarscope SV-60 Solarview H-alpha

"My interest in astronomy began when I was a teenager. Although I do a great deal of astronomy during the night, observing galaxies, nebulae, star clusters, planets and the constellations, my real passion lies with solar astronomy.

"Using my solar telescope and a Canon EOS 600D DLSR camera, I imaged a large prominence lifting off the solar limb a few years ago. The Sun was about to set behind the rooftops and some clouds were gathering in the western horizon as well. The prominence lifted off quite suddenly and it was over in a few minutes – luckily I was in the right place at the right time."



A solar prominence lifting off the limb of the Sun

Meade LightBridge Mini 130

Ideal for those looking to get into astronomy, this portable reflector is a worthy purchase for those on a budget

Telescope advice

Cost: £250 (approx. $149)
From: Hama UK Ltd
Type: Dobsonian
Aperture: 5.11"
Focal length: 25.6"

Best for...

- ? Beginners
- £ Small budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky

It's said that you should avoid purchasing a cheap telescope, however, this certainly shouldn't be applied to the Meade LightBridge Mini – the 'baby' version of the Meade LightBridge. It might be small, but overall this telescope is a worthy purchase for those looking to get into astronomy. If you have children that have been pestering you for a 'scope for some time, but you are worried about their interest in the night sky being a fad, then the LightBridge Mini is worth a look since it won't create much of a dent in your bank balance. We would go so far as saying that this latest edition to the Meade Instruments range could be used as a companion to a pre-existing telescope: if you are one who's keen to get a 'grab-and-go' 'scope, this instrument could be the one for you. As well as the 130mm, Meade also offers the LightBridge Mini with smaller apertures of 82mm and 114mm.

On first impressions, and even before you open the box, you know straight away that this telescope is massively portable. Keen to examine the Meade LightBridge Mini's build, we opened the box and were impressed even further – for the price the exterior is exquisite, giving an edge over other tabletop reflectors in the same price range. No cheap, plastic lenses and the tube and mount are finished to a very good quality. What's more, the 'scope comes already assembled and ready to tour the heavens within a few minutes – certainly something that beginners will see as a massive advantage. Many tabletop telescopes on the market only come with a single eyepiece, however, Meade Instruments has gone that extra mile by supplying a 9mm and a 26mm to provide magnifications of 72x and 25x, as well as a 2x Barlow lens. For the telescope's low price, the eyepieces are of very good build. The Meade LightBridge Mini also features a red dot finder and a 1.25" rack-and-pinion focuser – everything that you would expect on a 'scope for a beginner astronomer.

Since it is a tabletop 'scope the LightBridge Mini is best used on a sturdy table – if you use it in a similar way to a 'conventional' telescope, then you're very likely to get uncomfortable very quickly. Placing the telescope onto our garden furniture under a predawn sky, we put the 'scope's optics to the test. We enjoyed the smoothness of the telescope's 'turntable' base, which can be swivelled a full 360 degrees. A waning crescent Moon with 28 per cent illumination was our first target of choice before the Sun dominated the sky. It is at this time in the Moon's cycle where the beautiful surface features can be identified as sunlight meets dark along the terminator. Turning the telescope towards our target, with the 'higher power' 9mm eyepiece slotted into place, we gently turned the rack-and-pinion focuser to bring the lunar surface into crisp view. The branded knobs are of fair quality given the telescope's price and there is just about enough stiffness to slowly bring a target of interest into sharper view. For those not familiar with using a rack-and-pinion focuser, you may find using one can take a degree of practice, the LightBridge Mini's in particular took a bit of fiddling around with since it jumps from one focused view to another. Impressively the 'scope didn't vibrate as much as we expected as we turned the focusing knob and, once we had the left side of the Moon's northern hemisphere in our sights, we were blown away by the view that the 5.1-inch aperture was able to pick up. We were able to obtain a very good view of the lunar sea Oceanus Procellarium, as well as the crater Aristarchus and the rugged lunar surface along the terminator. Through the LightBridge Mini, views show a very good degree of clarity and contrast that's sure to delight fans of our natural satellite.

With the gas giant Jupiter shining at a magnitude of -2, we quickly turned the LightBridge Mini towards its brilliance in the constellation of Ophiuchus in the southeast, giving us the chance to try out the red dot finder – a feature of the telescope that did the desired job of finding our chosen object with ease. At a magnification of 72x, the king of the Solar System appeared as a brilliant bright disc with three of its moons – Io, Europa and Callisto – visible as

Above: Combining the eyepieces and 5.1" aperture, the tabletop Dobsonian provides magnifications of 72x and 25x, making it ideal for viewing the planets and lunar surface

Left: The LightBridge Mini is supplied with a red dot finder, suitable for 'hopping' from one star to the next

Right (inset): The telescope tube is attached to an alt-azimuth mount with a Vixen-style dovetail

Main: Weighing in at 6kg, the LightBridge Mini is very portable, making it ideal for all of the family to tour the night sky

> "Despite the telescope's low price, the eyepieces are of good build"

clear points of light. With the Sun's light brightening the sky, we waited until the evening to continue our observations with the LightBridge Mini.

Keen to observe the Orion Nebula (M42), we slewed the LightBridge Mini to the bright star-forming region smoothly and with ease. The sight of the nebula through the field of view was unmistakable, taking the form of a white, fuzzy patch of light with some members of the Trapezium star cluster visible. We could even make out the Andromeda Galaxy (M31) mid-evening – a delightful experience given that we could make out very slight detailing with averted vision. Star clusters such as the Pleiades (M45) in the constellation of Taurus are impressive through the LightBridge Mini at both magnifications, revealing the ever-so-slight nebulosity of the Merope Nebula (NGC 1435).

Ideal for those just starting out in astronomy, the LightBridge Mini is an excellent beginner's telescope that's also suitable for those looking for a fuss-free instrument to compliment their existing kit – and a piece that delivers great views.

WIN

WORTH £250!

MEADE LIGHTBRIDGE MINI 130

Suitable for all ages of any experience, this grab-and-go Dobsonian is perfect for revealing a host of magnificent celestial sights

This Dobsonian is just short of a metre (three feet) in height, but as the old saying goes: "Good things come in small packages." That is definitely the case with the Meade LightBridge Mini 130, which has been supplied courtesy of Hama UK Ltd. With an aperture of 130 millimetres (five inches), it's more than capable of zooming in on planets, bright deep-sky targets and stars with its exquisite and beautifully crafted light-collecting optics.

The telescope tube sits on a swivel base with horizon and vertical movement; a favourite with amateur astronomers due to its simplicity, boasting ease of navigation that makes slewing from one target to the next a breeze. The 'scope is supplied with a red dot finder, a 2x Barlow lens plus two eyepieces - a 9mm and 25mm - which supply magnifications of 72x and 25x, respectively. It's the perfect companion for observing a wide selection of astronomical targets.

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The latest books, apps, software, tech and accessories for space and astronomy fans alike

1. App **Star Walk HD**

Cost: £2.29/$3.49 **From:** iTunes and Google Play

Star Walk HD has been praised for the beauty of its graphics, as well as being granted the title of "the most beautiful stargazing app", and we really couldn't agree more. With over 8 million users and winner of the Apple Design Award 2010, Star Walk really is ideal for anyone interested in astronomy and learning their way around the night sky. Fully interactive and able to reveal the exact positions of objects in the sky above you at any one time, Star Walk HD allows the user to learn everything they need to know about the night sky at their own pace.

Downloading the app to an iPad was a breeze and we were up and running in no time. We especially enjoyed using the rewind and fast-forward time so that we could work out where a particular object moved. Holding our device up to the sky, the app – with the help of GPS – quickly identified the constellations in the Northern Hemisphere and allowed us to identify a variety of targets, which we could later follow up with our telescope. Pointing it towards the ground, we could see all of the stars and objects in the Southern Hemisphere. Quite handy for the observer, the app also has rise and set times for the planets so that you can plan your observing sessions.

2. Software **Virtual Planetarium**

Cost: £25.45 /$39.95 **From:** Name A Star Live

Virtual Planetarium includes interactive sky maps and a large library of imagery along with information on the Solar System and the most recent information on astronomical events. This software is ideal for budding astronomers keen on finding their way around the night sky while learning more about our solar neighbourhood, often through the medium of movies.

This software is ideal for users of Windows and Macintosh machines, making it very versatile, and we enjoyed the unique Space Weather program that allows the user to explore forecasts of the aurorae and solar flares from our nearest star. .

We took advantage of a clear evening in February to see how the integrated 'Sky Tonight' star charts fared. Loading the star maps, which have a very basic design, we could use it to find constellations in the night sky with ease after hitting 'Play'. We were also able to find planets and deep-sky objects without too much trouble, which we followed up using a telescope.

Virtual Planetarium is an adequate planetarium for the budding astronomer. However, given that its graphics are quite basic, the software does take up a large amount of storage.

3. Binoculars **Celestron UpClose 10x50**

Cost: £45 **From:** Celestron

Both the image quality and build of the Celestron UpClose 10x50 binoculars are exceptional, with BAK4 prisms providing clear and sharp views of the Moon's surface as well as Jupiter and its moons, which appeared as an obvious white disc with small points of light snuggled close by. The binoculars are light and easy to hold, ensuring comfortable observing for long periods of time. Being well-built and waterproof is a massive plus, making these binoculars ideal for nature watching during the day. Twist eyecups provide very long eye relief.

The Celestron UpClose are very well collimated and the lenses are beautifully coated, but we did detect a slight amount of colour-fringing when observing brighter targets. This didn't detract from the excellent experience we received from these reasonably priced binoculars though, and they are one of the best pairs of 10x50s we have used.

> "The *Yearbook* warrants a place on the bookshelf of all sky watchers and stargazers"

4. Book Yearbook of Astronomy 2019

Cost: £16.99 **From:** Pen and Sword Books Limited

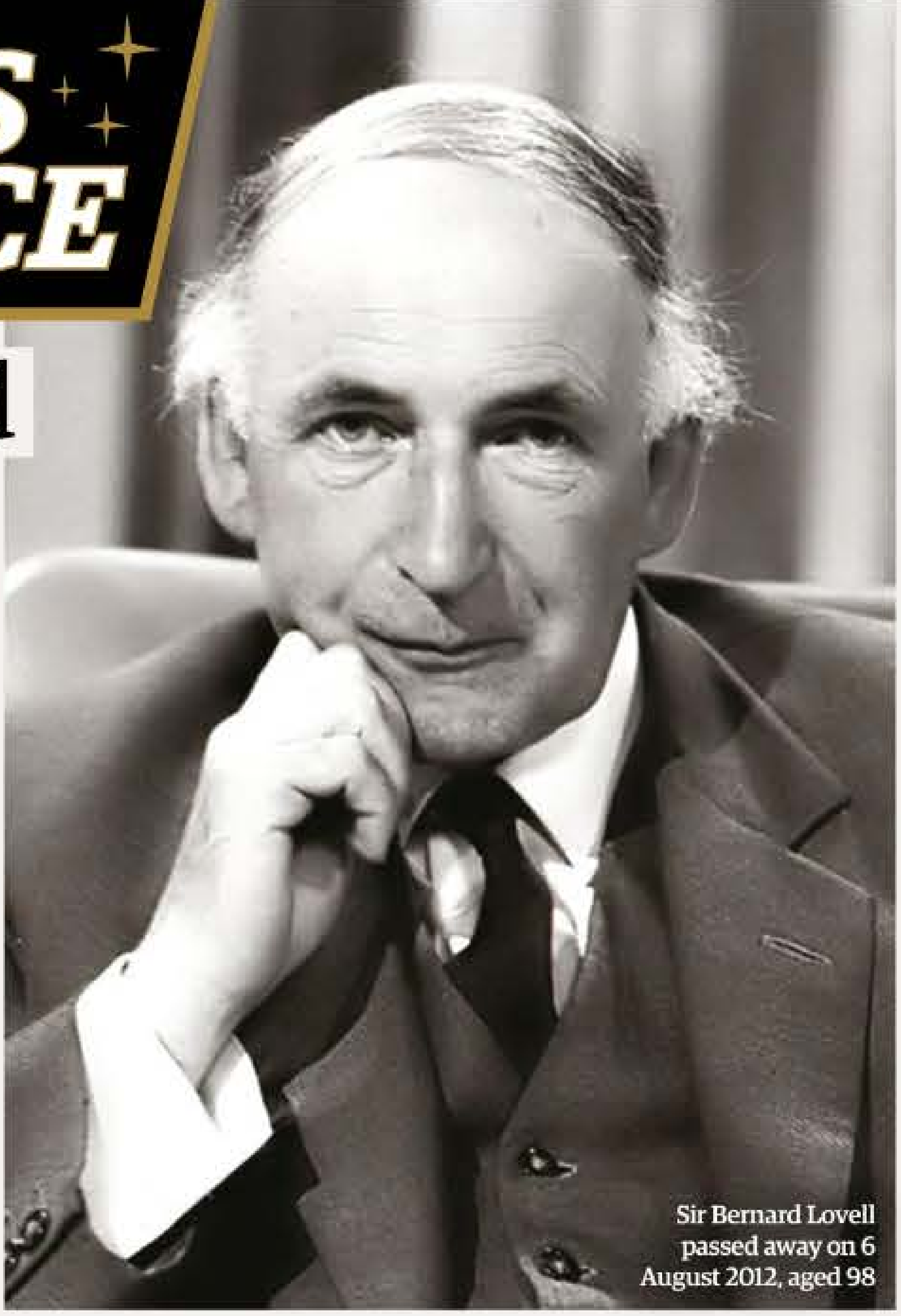
An inspiration to amateur and professional astronomers alike, the *Yearbook of Astronomy* warrants a place on the bookshelf of all sky watchers and stargazers. Maintaining its appealing style and presentation, its pages contain an authoritative set of sky charts and comprehensive jargon-free monthly sky notes to enable backyard astronomers everywhere to plan their viewing of the year's eclipses, comets, meteor showers and deep-sky objects. In addition a variety of entertaining and informative articles present the reader with information on a wide range of topics including, among others, the Cassini-Huygens mission to the Saturn system, 100 years of the International Astronomical Union, the first micro-quasar, getting the measure of double stars, Asaph Hall: man of Mars and science fiction and the future of astronomy.

Solar Distance 10^6 km 1426
Radius km 60268
Mass kg 5.685E+26
Orbit Period Days 10755
Rotation Period Earth days 0.44401
Surface Gravity x Earth 1.06
Tilt Degrees 26.73
Density g/cm^3 0.70
Temperature °C -178
Eccentricity 0 to 1 0.05415

Saturn is the sixth planet from the Sun, the second largest, and has the most extensive ring system of any of the gas giants. Early observations of Saturn were complicated by the fact that the Earth passes through the plane of Saturn's rings every few years as Saturn moves in its orbit (see Saturn's NEW images). A low resolution image of Saturn therefore changes drastically. In this image, several dark spoke-like features can be seen across the broad B ring (left of planet). The moons Rhea and Dione appear as dots below and to the right of the planet. Saturn is visibly flattened. Its oblateness is almost 10%. This is the result of its rapid rotation and fluid state. Saturn is the least dense of the planets; its specific gravity (0.7) is less than that of water. This photo was taken in 1981 by Voyager 2, when the spacecraft was 33.9 million km from the planet.

Sir Bernard Lovell

The man behind Jodrell Bank Observatory



Sir Bernard Lovell passed away on 6 August 2012, aged 98

Sir Bernard Lovell was a physicist ahead of his time, and one of the key figures in radio astronomy. His influence on radio astronomy, not just in the United Kingdom, but around the world, paved the way for some of the most exciting discoveries made since the Second World War.

Lovell was born on 31 August 1913 in Bristol, England. He showed a keen interest in science and astronomy from an early age, but this was put on hold due to the outbreak of World War II. After the war ended he began taking seemingly obsolete radio equipment out to an empty field in the middle of the woods in Cheshire, England.

When he wasn't playing his beloved cricket he was turning ex-military radar equipment into tools with which he could conduct radio astronomy. This is thought of as the birth of Jodrell Bank Observatory, which at the zenith of its power was the world's largest steerable telescope – it still remains the third-largest at the time of writing.

Although Lovell's radio astronomy in the woods of Cheshire had been ongoing since 1945, his 76-metre (250-foot) diameter steerable radio telescope, which peeps its head above the trees at a height of 89 metres (290 feet), wasn't fully assembled until the summer of 1957. It was named Lovell's Telescope in 1987 after the great man himself, but before that it was known as the 'Mark I Telescope'. This telescope was not easy to build, but it was even more difficult to sell to the public. Questions from the government came about as tax-payers' money was being used to construct such a feat in radio astronomy. Interest grew when the public saw it play a huge role in the Space Race, the race between the United States and the Soviet Union in who could reach space first.

In 1957 tensions and egos were high as the two superpowers were battling for space supremacy. In the same summer as the amazing telescope construction was completed, the Soviets launched the first artificial satellite into space: Sputnik 1. Although the satellite itself wasn't hard to detect from anywhere on Earth, the Lovell Telescope showed the world its prowess in tracking the booster rocket that accompanied it in its orbit. This caught public and government attention because as far as they knew, the next rocket could be a missile.

Because of this attention the United States and the Soviet Union would contact Lovell himself so that any satellites, rockets and missions to the Moon could be traced. This included confirming the impact of the USSR's Luna II in 1959, the first man-made object to hit another celestial object, in this case the Moon.

This played a huge role in the media, and Lovell was appointed the first director of Jodrell Bank Observatory, calling the shots. The telescope did continue to make scientific observations simultaneously as it observed the universe in a wavelength imperceivable to the human eye. This told us many things about the Solar System, its planets, the Sun, meteors and even far beyond to other galaxies.

The Jodrell Bank Observatory is run by the University of Manchester

© Mike Peel; Jodrell Bank Centre for Astrophysics, University of Manchester

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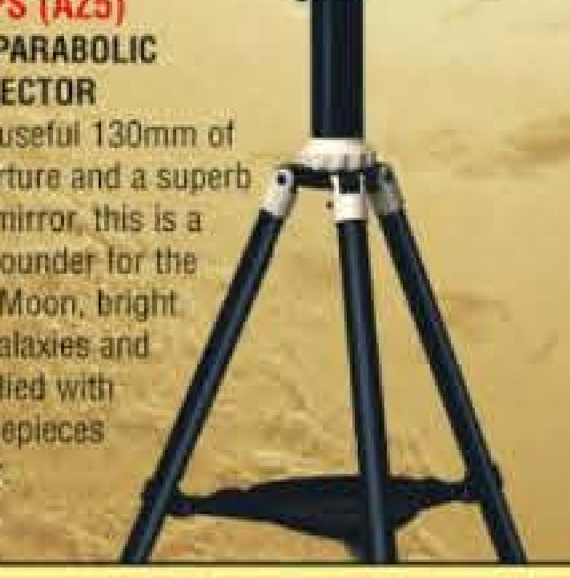

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